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RAY T. BAYLESS, *Editor*

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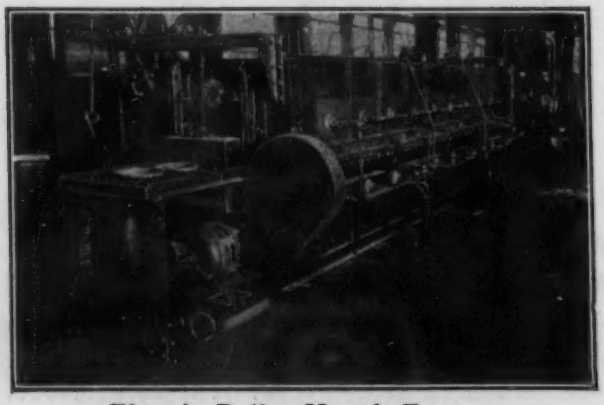

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TRANSACTIONS
American Society for Steel Treating

VOL. XIV DECEMBER, 1928 NO. 6

DECARBURIZATION OF HIGH CARBON STEEL IN "REDUCING" ATMOSPHERES

By J. J. Curran and J. H. G. Williams

Abstract

Many instances have been observed by the authors of soft skin in high carbon steel parts which have been hardened under different commercial conditions but usually when precautions were taken to minimize scaling. A soft skin was also noted on high carbon tool and alloy steels although heated for hardening under reducing conditions.

Tests carried on by the authors indicate that carbonaceous packing mixtures may be either carburizing or decarburizing in their action, depending on the activating materal used in the mixture and on the temperature of heat treatment. It is concluded that packing materials used to protect steel during heating operations probably are responsible for the skin softness of the steel after heat treatment.

HIGH carbon steels, as tool and spring steel, for instance, often present serious difficulties because the surface, after heat treatment, lacks the hardness to meet the service requirements. Surface decarburization originating in heat treating or during earlier manufacturing operations is frequently the cause of such difficulties.

Under the title "Note on a Curious Case of Decarburization

A paper presented before the tenth annual convention of the society held in Philadelphia, October 8 to 12, 1928. Of the authors, who are members of the society, J. J. Curran is metallurigst with the Harrisburg Pipe Bending and Machine Company, Harrisburg, Pa., and J. H. G. Williams is metallurgical engineer with the Henry Souther Engineering Co., Hartford, Conn. Manuscript received July 9, 1928.

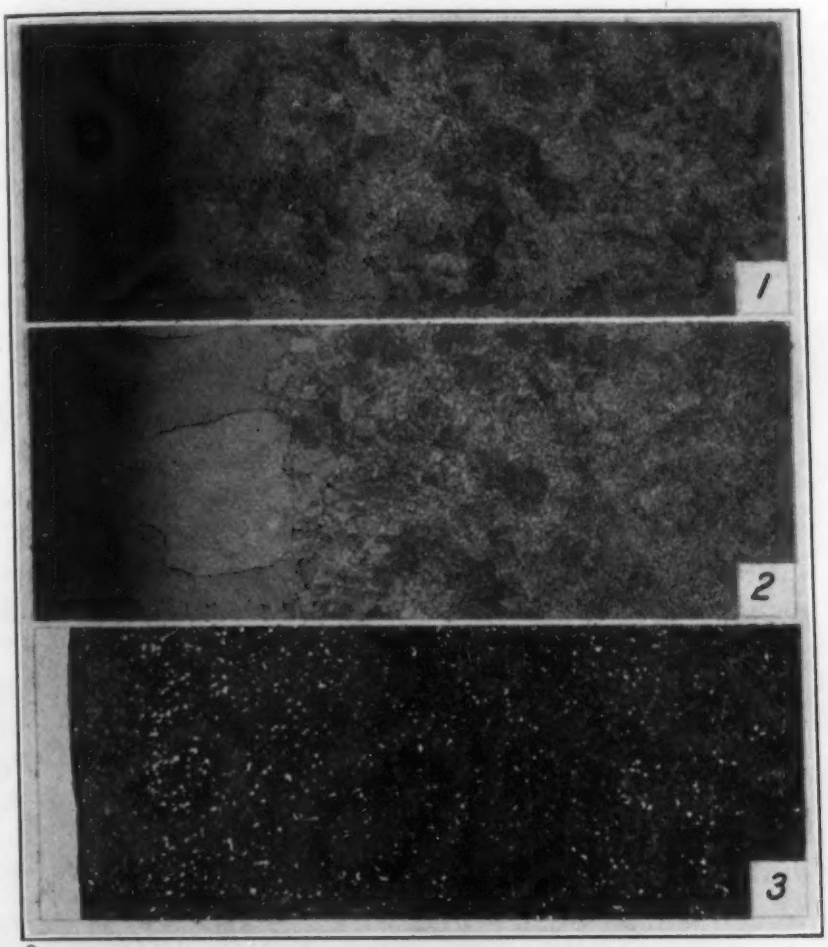
During the Hardening of Steel Dies," Greenwood (1)[1] describes an instance of soft surface skin on the faces of hardened dies which had been carefully protected from scaling during hardening by covering with powdered charcoal. Beneath the soft skin the steel showed satisfactory hardness. Investigation proved that this soft skin was due to decarburization of the steel by the charcoal protecting cover. Dies similarly treated, but without charcoal protection, were hard on the surface, and decarburization was less marked.

We have observed many instances of soft skin in high carbon steel parts hardened under many different conditions of commercial practice but usually when precautions were being taken to minimize scaling. High carbon tool and alloy steels have come to our attention with a soft skin although heated for hardening under reducing conditions, as in semi-muffle type gas furnaces operated with an excess of fuel, and in tightly sealed metal retort electric furnaces, where the parts charged were coated with oil from machining operations, or when coal, charcoal, or carburizing compound was thrown into the retort to prevent scaling. In all of these instances, the scaling was relatively slight or entirely absent, but the product showed a soft skin of varying depth, below which the metal was hard.

In all the cases mentioned, the original surface had been removed by machining operations. Since relatively short exposure to decarburizing influences produces skin decarburization in hardening, it might be expected that even more serious decarburization would result from the more prolonged exposure to which the steel is subjected in annealing operations, even though under protection of presumably "reducing" or "non-oxidizing" atmospheres.

Figs. 1 and 2 show the structures of the surface skin of two bars of the same steel, containing about 1.10 per cent carbon. The first bar was annealed commercially in an iron tube with the ends loosely sealed with clay, and at the same time, in a similar tube in the same furnace, the second bar was annealed, but with charcoal added to prevent scaling. As shown in the photomicrographs, little or no distinct decarburization occurred in the case of the unprotected bar, whereas an appreciable and distinctly visible

[1]The figures appearing in parentheses refer to the bibliography appended to the paper.



Figs. 1 to 3—Photomicrographs Showing the Structure of the Surface Layer of 2 Bars of the Same Steel Containing 1.10 Per Cent Carbon. Fig. 1—Annealed Commercially in an Iron Tube with Ends Loosely Sealed with Clay. Fig. 2—Annealed in a Similar Manner to Fig. 1 but with Charcoal Added to Prevent Scaling. Fig. 3—Shows a Type of Decarburization in a Similar Bar which has been Hardened and Tempered to a Spring Temper After a Large Number of Cold Rolling Operations with Intermediate Annealing Treatments. The Steel was Protected Against Scale by Passing a Current of Illuminating Gas Through the Annealing Pot. Figs. 1 and 2 Etched in 1 Per Cent Nital for 30 Seconds. Fig. 3 Etched 20 Seconds in 1 Per Cent Nital. × 100.

loss of carbon did occur in the protected bar, resulting in a completely decarburized surface, as shown by the rim of ferrite, with an underlying partially decarburized zone of ferrite and lamellar pearlite. The total depth of the zone of lowered carbon content is approximately 0.020 inch.

In material which is to be machined after annealing, moderate decarburization resulting from annealing is not a serious difficulty. In drill rod, or in other stock which is not to be machined,

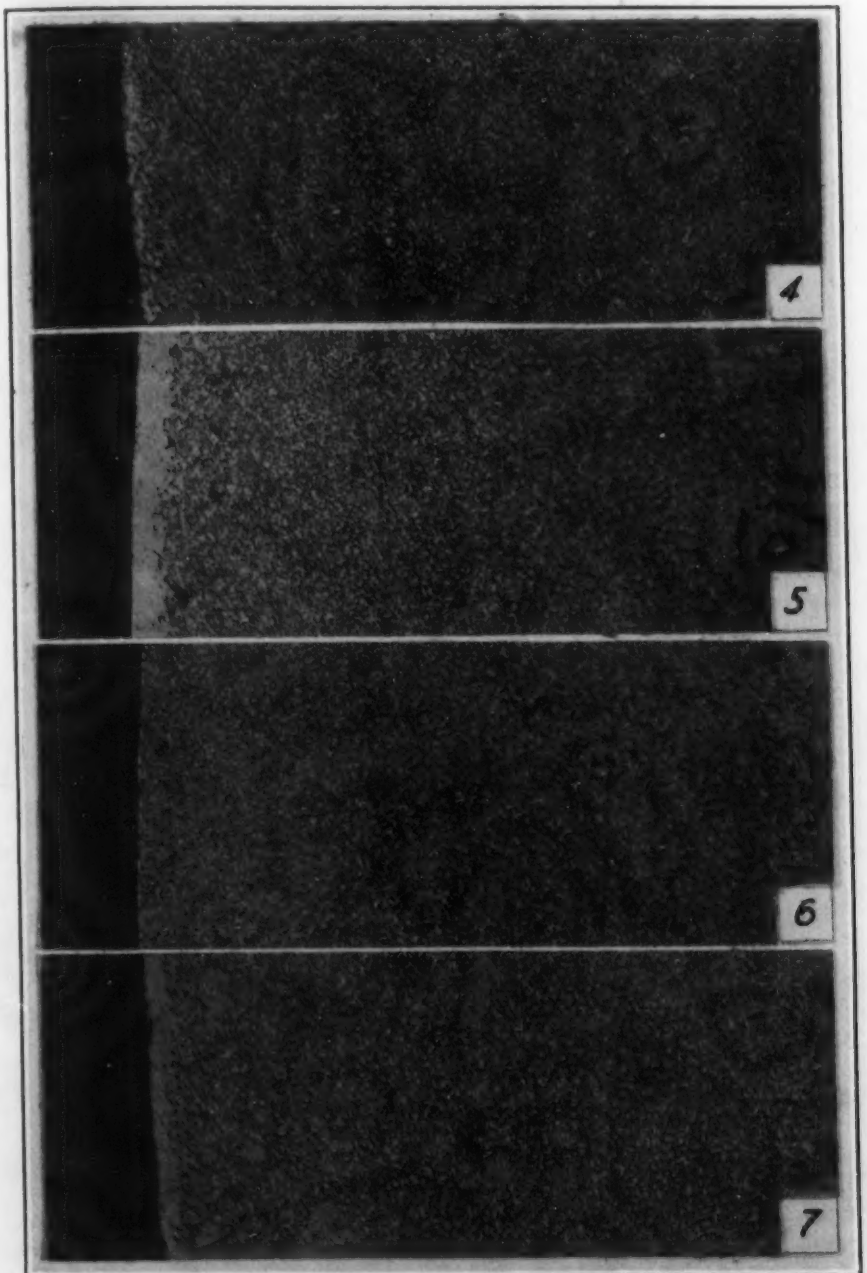
and which must harden uniformly to the extreme surface, it does constitute a serious difficulty. As an illustration, thin flat spring stock which has a lowered carbon content in the surface layers, might fail prematurely by "setting" under relatively low loads, or by fatigue in service. Fig. 3 shows a type of decarburization sometimes encountered in this material, in a sample which has been hardened and tempered to a spring temper, after a large number of successive cold rolling operations and intermediate annealing treatments. The annealing treatments were conducted at a temperature close to, but below, the critical point. During the annealing operations, the material was protected against scaling by passing a current of illuminating gas through the annealing pot.

The structure shown in Fig. 3 is particularly interesting in that it not only shows a partially decarburized rim about 0.003 inch deep, in which the characteristic spheroids of excess cementite are absent, but also an underlying zone in which the spheroids of cementite are more numerous than in the unaltered interior of the metal. The actual cause of this phenomenon is not clear, but it is possibly a result of carbon absorption during the soaking portion of the successive anneals, followed by partial decarburization during the periods of cooling from the annealing temperature—all at a temperature just below the critical point.

Examination of the literature on the subject of surface decarburization discloses much that is contradictory. It does indicate, however, that the subject is complex, and that there are at least several factors which determine whether or not a given protecting medium or packing material will be carburizing, neutral, or decarburizing.

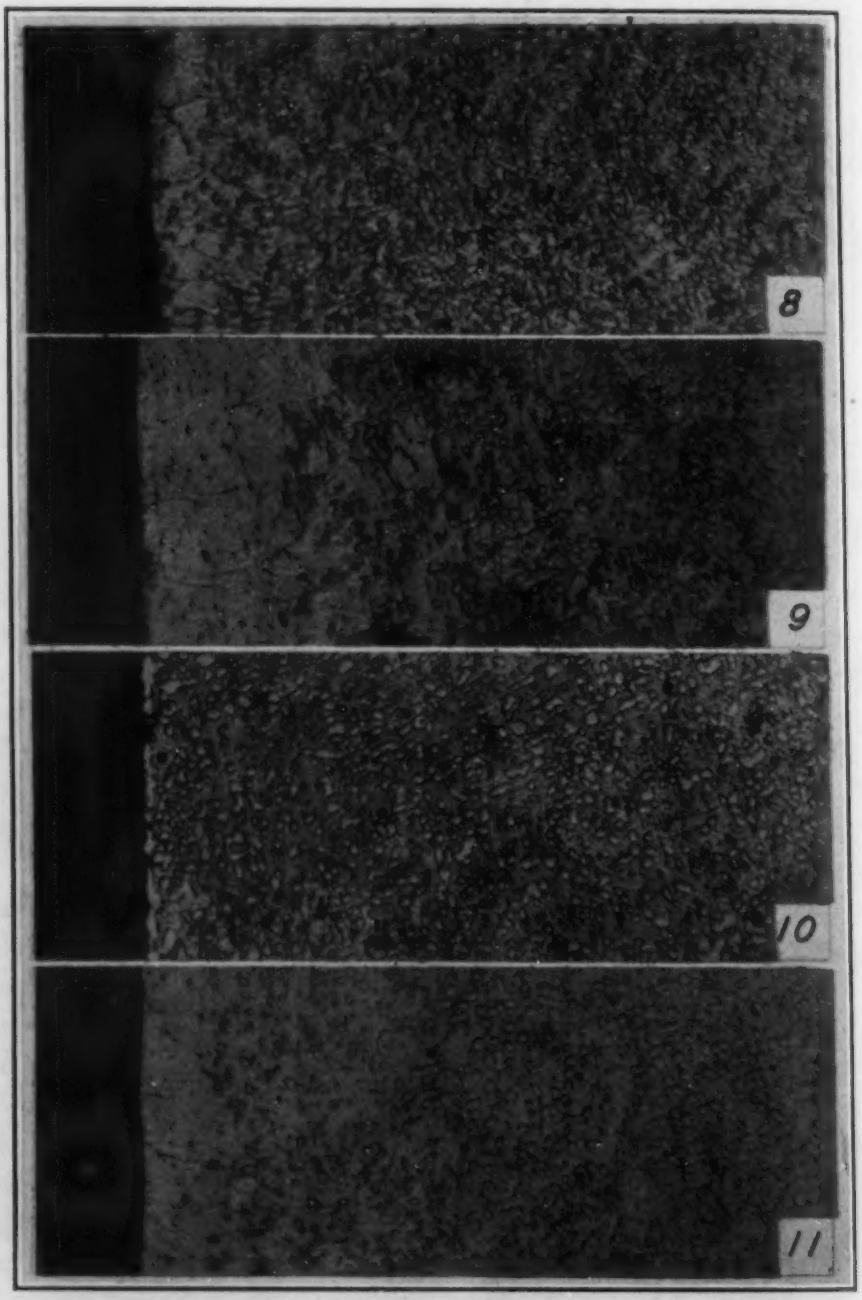
Portevin (2) has shown that salt baths containing high percentages of ferrocyanides and cyanides, usually considered as carburizing agents, actually lower the carbon content on the surface of high carbon steel, while at the same time increasing the carbon content of low carbon steel. In other words, such a mixture, at a given temperature, can either carburize or decarburize, depending on the carbon content of the steel treated, the surface ultimately reaching equilibrium at about 0.30 per cent carbon content.

Emmons (3) reports experimental results showing that steel is decarburized at temperatures above the critical point by CO_2, air, oxygen, and steam, and when iron oxide is present, by CO or



Figs. 4 to 7—Photomicrographs of 1.15 Per Cent Carbon Steel, Heated for 4 Hours at 1275 Degrees Fahr. and Cooled Slowly in Furnace. Fig. 4—Packed in Charcoal. Fig. 5—Packed in Charcoal Plus 10 Per Cent Sodium Chloride. Fig. 6—Packed in Charcoal Plus 10 Per Cent Sodium Carbonate. Fig. 7—Packed in Charcoal Plus 10 Per Cent Barium Carbonate. All Specimens Etched for 30 Seconds in 1 Per Cent Nital. × 100.

by charcoal. Hydrogen or CO alone were found to produce no effects. No decarburization was found to occur in any case at temperatures below the critical point.



Figs. 8 to 11—Photomicrographs of 1.15 Per Cent Carbon Steel, Heated for 4 Hours at 1275 Degrees Fahr., and Cooled Slowly in Furnace. All Specimens Etched 30 Seconds in 1 Per Cent Nital. Fig. 8—Packed in Charcoal. Fig. 9—Packed in Charcoal Plus 10 Per Cent Sodium Chloride. Fig. 10—Packed in Charcoal Plus 10 Per Cent Sodium Carbonate. Fig. 11—Packed in Charcoal Plus 10 Per Cent Barium Carbonate. × 500.

Langenberg (4) has shown that a piece of white cast iron, containing 2.5 per cent carbon, and 1.1 per cent silicon, in a sec-

tion 1 inch wide by ¼ inch thick, was decarburized throughout to an average carbon content of 0.50 per cent, by annealing at 1875 degrees Fahr. in a current of illuminating (city) gas—a medium commonly considered as nondecarburizing, or even carburizing. The same gas failed to carburize a practically carbonless steel (ingot iron), except when a large excess of solid carbon was present in the annealing chamber. Hence, at atmospheric pressure, illuminating gas of the composition used appears to be a decarburizing agent.

Campbell, in his work (5), shows that steels of widely varying compositions can all be nearly completely decarburized by heating for a sufficient period at 1650 to 1920 degrees Fahr. (900 to 1050 degrees Cent.) in hydrogen.

Austin (6) showed that hydrogen, wet or dry, will decarburize steels of 0.40 to 1.27 per cent carbon content, at temperatures from 1256 to 1832 degrees Fahr. (680 to 1000 degrees Cent.) In discussion of this paper, Rosenhain called attention to the fact that decarburization will occur when steel is heated in high vacuum, in hydrogen, in nitrogen, in fact, under almost any condition where actual carburization does not occur. In his experimental work, the only practical method of preventing decarburization was by the use of hydrocarbons, in fact carburization. In the same discussion, Greenwood called attention to serious decarburization which occurs during commercial annealing operations on steel strip and wire, even when packed in cast iron chips. Rosenhain and Greenwood agree that carbon is soluble in iron, to a slight extent, at least, below the critical point.

Knowlton (7) has described decarburization following normal carburization, in cooling from the carburizing temperature.

Johansson and Von Seth (8) studied the decarburizing effects of various gaseous mixtures, and pointed out that the rate of penetration of decarburization was materially reduced under conditions which caused the formation of surface scale.

Schulz and Hulzbruck (9) state that decarburization of steel occurs in practically all gases and mixtures which are not actually carburizing. Treatment in pure nitrogen or very careful packing in cast iron chips they consider to be practically "nondecarburizing", but they believe that only methane-hydrogen mixtures are actually neutral.

Fishel and Woodell (10) report that carbon monoxide will carburize iron at temperatures between 1470 and 2010 degrees Fahr. (800 and 1100 degrees Cent.).

Sykes (11) describes experiments carried out to determine the carburizing and decarburizing effects of hydrogen-methane mixtures, and gives figures for the composition of atmospheres neutral to steels of various carbon contents at different temperatures.

Guthrie and Wozasek (12) report variable carburization from city gases of the same proximate composition, with all other conditions equal, and describe means of overcoming these variations.

The preponderance of evidence from all of these investigations is to the effect that most of the supposedly reducing and inert mixtures, whether gaseous, liquid, or solid, are in reality often decarburizing agents under the conditions of temperature and pressure normally encountered in the heat treatment of high carbon steels.

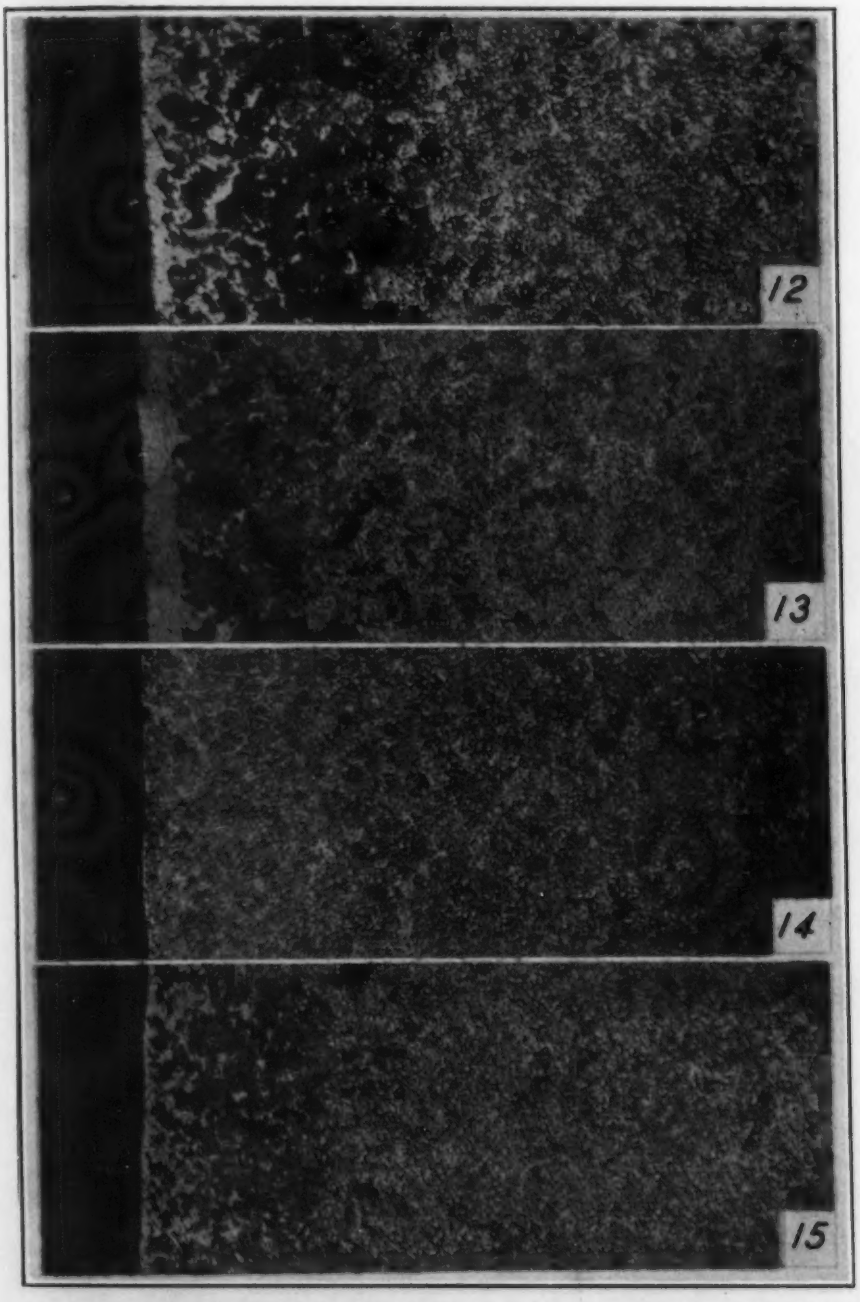
Some five or six years ago an extended research was planned by the authors, to include studies of the carburizing and decarburizing tendencies of the materials used commercially as protective media in "bright" annealing and hardening, as well as to explore the field of less commonly used materials. Part of this work is now described here.

As one step in the program, it was decided to determine the effect of extremely reducing carbonaceous atmospheres such as produced by carburizing compounds, etc., when used to "pack-harden" steel. The tests were conducted upon drill rod, the analysis of which was as follows:

	Per Cent
Carbon	1.15
Manganese	0.28
Silicon	0.19

The drill rod (½ inch diameter) was cut into 4-inch lengths and machined to ⅜ inch in diameter to remove any decarburized skin that might have been present originally. The 4-inch lengths were then subjected to annealing treatments, packed in four different mixtures, i.e.,

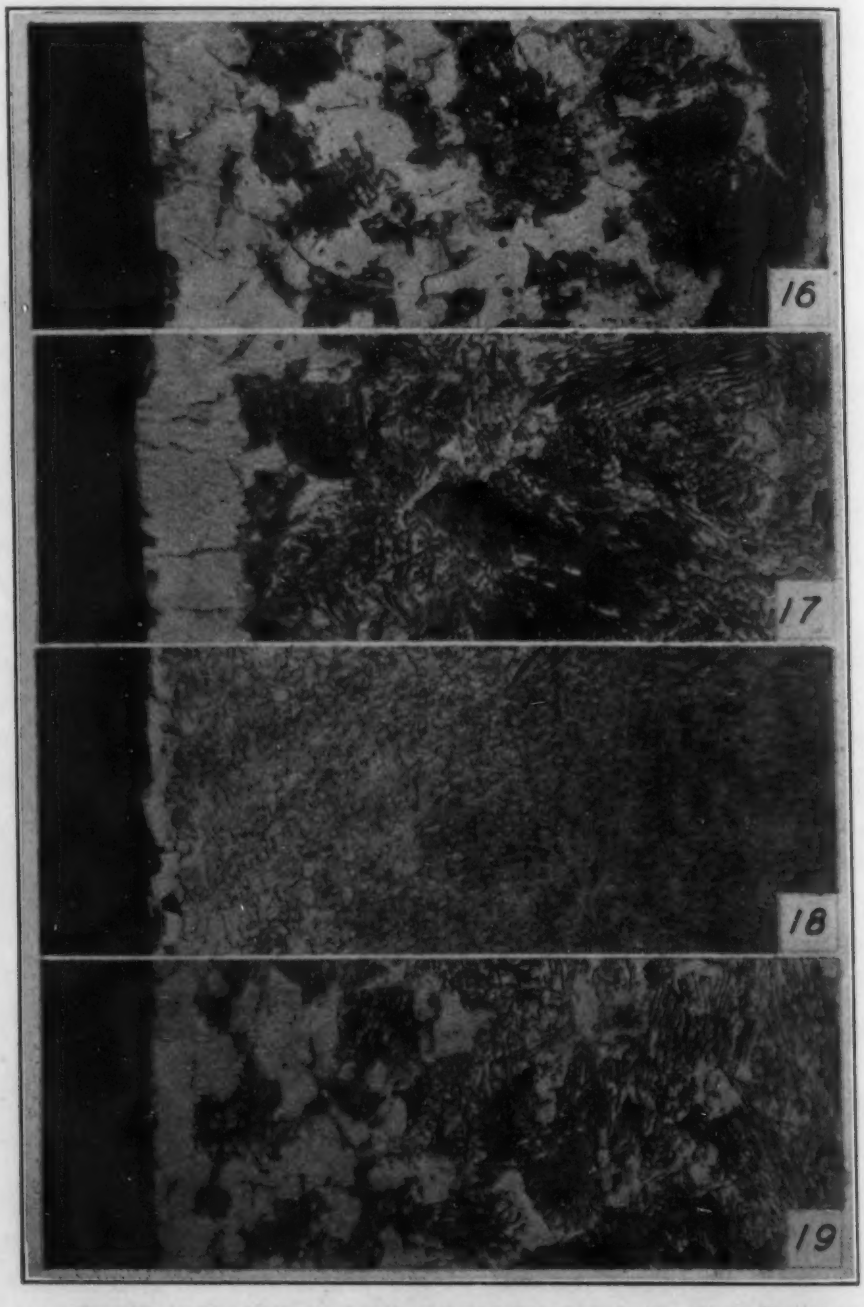
1. Powdered charcoal
2. Powdered charcoal plus 10 per cent sodium chloride
3. Powdered charcoal plus 10 per cent sodium carbonate



Figs. 12-15—Photomicrographs of 1.15 Per Cent Carbon Steel, Heated for 4 Hours at 1425 Degrees Fahr., and Cooled Slowly in Furnace. All Specimens Etched 30 Seconds in 1 Per Cent Nital. Fig. 12—Packed in Charcoal. Fig. 13—Packed in Charcoal Plus 10 Per Cent Sodium Chloride. Fig. 14—Packed in Charcoal Plus 10 Per Cent Sodium Carbonate. Fig. 15—Packed in Charcoal Plus 10 Per Cent Barium Carbonate. × 100.

4. Powdered charcoal plus 10 per cent barium carbonate.

The annealing containers consisted of suitable lengths of 2-



Figs. 16 to 19—Photomicrographs of 1.15 Per Cent Carbon Steel, Heated for 4 Hours at 1425 Degrees Fahr., and Cooled Slowly in Furnace. All Specimens Etched 30 Seconds in 1 Per Cent Nital. Fig. 16—Packed in Charcoal. Fig. 17—Packed in Charcoal Plus 10 Per Cent Sodium Chloride. Fig. 18—Packed in Charcoal Plus 10 Per Cent Sodium Carbonate. Fig. 19—Packed in Charcoal Plus 10 Per Cent Barium Carbonate. × 500.

inch water pipe, with caps on each end, drilled with a small vent hole. Four such containers, each containing a specimen packed

in one of the four packing materials, were annealed at the same time in a gas-fired semi-muffle furnace. The temperatures and times of heating were as follows:

1. Heated to 1275 degrees Fahr., held at heat 4 hours, cooled slowly with the furnace.
2. Heated to 1425 degrees Fahr., held at heat 4 hours, cooled slowly with the furnace.
3. Heated to 1675 degrees Fahr., held at heat 2 hours, cooled slowly with the furnace.

The above treatments correspond to anneals (1) below the critical range, (2) in the usual annealing and hardening range for this type of steel, and (3) in the range devoted to the carburizing of low carbon steels, respectively.

After these treatments the specimens were mounted in drilled steel blocks, to preserve the edges, and cross-sections were prepared for microscopic examination. The microstructures of the surface layers produced by the heat treatments are shown in Figs. 4 to 27. For convenience in demonstrating the effect of the various packing media, these are grouped according to heat treatments, i.e., the figures in each plate show the degree of decarburization resulting from the four different packing materials at a given temperature.

Decarburization in a steel of the composition employed is indicated by several different types of structure, depending on the degree of decarburization and the temperature at which it occurred. The most obvious type of decarburized structure is that characterized by a rim of pure ferrite. Such a rim does not usually indicate the total depth of decarburization, however.

Where the material is originally in the spheroidized condition (as in the case of the drill rod used here) and the annealing treatment subsequently applied is at a temperature below the critical range, the ferrite rim will be accompanied by a less distinctly recognizable decarburized zone in which the spheroids of cementite are less numerous than in the body of the metal.

When the annealing treatment applied is at a temperature above the critical range, but not high enough to form lamellar pearlite in the body of the metal, two other structures may be present in succeeding layers below the ferrite rim. The first will

Table I
Depth of Decarburization

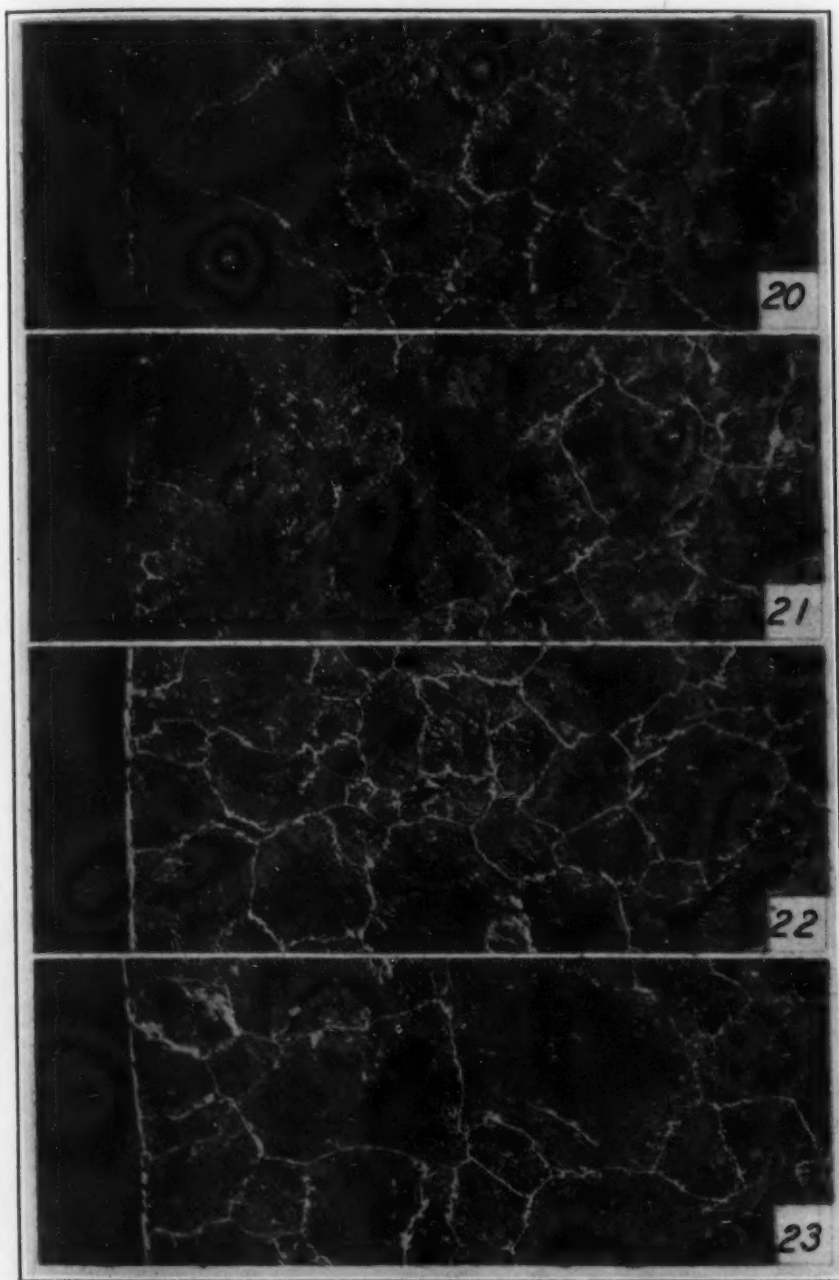
Treatment	Depth of Decarburization Inches	Fig.
1275 degrees Fahr.—4 hours—furnace cooled. Packed in		
Charcoal	0.001	4 — 8
Charcoal plus sodium chloride	0.004	5 — 9
Charcoal plus sodium carbonate	none	6 — 10
Charcoal plus barium carbonate	0.002	7 — 11
1425 degrees Fahr.—4 hours—furnace cooled. Packed in		
Charcoal	0.0123	12 — 16
Charcoal plus sodium chloride	0.010	13 — 17
Charcoal plus sodium carbonate	none	14 — 18
Charcoal plus barium carbonate	0.009	15 — 19
1675 degrees Fahr.—2 hours—furnace cooled. Packed in		
Charcoal	0.0005	20 — 24
Charcoal plus sodium chloride	trace	21 — 25
Charcoal plus sodium carbonate	none	22 — 26
Charcoal plus barium carbonate	none	23 — 27

consist of grains of ferrite and lamellar pearlite, the other will consist entirely of lamellar pearlite, merging into the spheroidal structure in the unchanged body of the metal. The presence of the pearlitic layer makes the total depth of decarburization easily and quite accurately measurable.

At high temperatures, as in the carburizing range, a rim of ferrite may appear, followed by ferrite-pearlite and pearlite zones, as above. The final layer of decarburized material, however, will be distinguishable from the lamellar pearlite-cementite network structure of the body of the metal by the tapering off of the cementite networks.

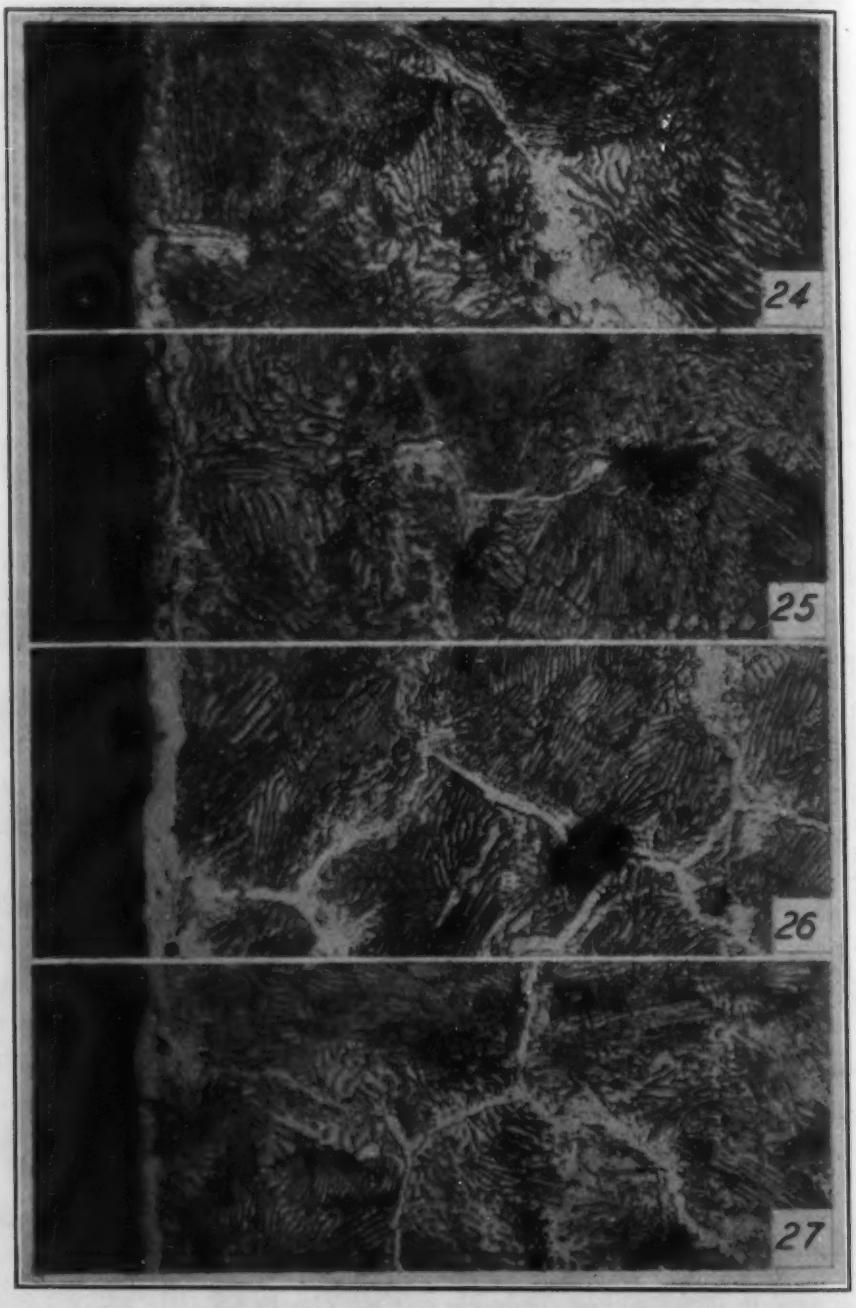
Carburization, on the other hand, does not progress normally at low temperatures in a steel of this type, hence it appears only as a thin continuous carbide layer on the surface. At temperatures in the carburizing range, above the A_{cm} point of the steel, solution and diffusion will occur, resulting in an increase of cementite networks in the surface zone.

These characteristics have been used to determine the total depth of decarburization or presence of carburization in this instance. The total depths of decarburization observed in the various specimens are shown in Table I.



Figs. 20 to 25—Photomicrographs of 1.15 Per Cent Carbon Steel, Heated for 2 Hours at 1675 Degrees Fahr., and Cooled Slowly in Furnace. All Specimens Etched 30 Seconds in 1 Per Cent Nital. Fig. 20—Packed in Charcoal. Fig. 21—Packed in Charcoal Plus 10 Per Cent Sodium Chloride. Fig. 22—Packed in Charcoal Plus 10 Per Cent Sodium Carbonate. Fig. 23—Packed in Charcoal Plus 10 Per Cent Barium Carbonate. × 100.

Table I and the Figs. are arranged to permit comparison of the effects of the four packing materials at each of the four an-



Figs. 24 to 27—Photomicrographs of 1.15 Per Cent Carbon Steel, Heated for 2 Hours at 1675 Degrees Fahr., and Cooled Slowly in Furnace. All Specimens Etched for 30 Seconds in 1 Per Cent Nital. Fig. 24—Packed in Charcoal. Fig. 25—Packed in Charcoal Plus 10 Per Cent Sodium Chloride. Fig. 26—Packed in Charcoal Plus 10 Per Cent Sodium Carbonate. Fig. 27—Packed in Charcoal Plus 10 Per Cent Barium Carbonate. × 500.

nealing temperatures used. The effect of temperature, for each of the packing materials used, may be summarized as follows:

1. Packed in charcoal.

Specimens packed in charcoal alone showed evidence of decarburization at all three annealing temperatures. Decarburization was most marked in the specimen annealed at 1425 degrees Fahr.

2. Packed in charcoal plus 10 per cent sodium chloride.

Specimens packed in charcoal-salt mixture showed appreciable decarburization after annealing at 1275 and 1425 degrees Fahr., and but a trace of decarburization when annealed at 1675 degrees Fahr. For practical purposes, therefore, the mixture may be considered as decarburizing for all temperatures in the usual hardening and annealing ranges for steel.

3. Packed in charcoal plus 10 per cent sodium carbonate.

Specimens packed in the charcoal-sodium carbonate mixture showed no decarburization at any of the three temperatures used. On the contrary, a peculiar carburizing action was observed at 1275 degrees Fahr., below the critical range, and at 1425 degrees Fahr., just above the critical range, and a normal carburizing action was observed at 1675 degrees Fahr., in the usual carburizing range.

The carburizing observed at the lower temperatures was not deep, consisting only of a thin shell of massive carbide completely covering the surface. This carbide shell appeared also on the surface of the specimen annealed at the highest temperature. Etching with alkaline picrate reagent served to identify the material as massive carbide.

4. Packed in charcoal plus barium carbonate.

The charcoal-barium carbonate mixture had an effect similar to charcoal alone at the lower temperatures, but carburized actively at 1675 degrees Fahr., forming a shell of massive carbide similar to that produced at the same temperature by the charcoal-sodium carbonate mixture.

These tests indicate, therefore, that carbonaceous packing mixtures used for pack-hardening or pack-annealing may be either carburizing or decarburizing in their action, depending on the activating material used in the mixture, and on the temperature at which the heat treatment is performed.

Other variables which undoubtedly are important are the

composition of the steel, and the concentration of the activating material in the carbonaceous material.

While our tests do not cover the effect of these variables, the work described, considered in conjunction with that of other investigators already mentioned, casts some light on both. Three of the mixtures show a variation in action from decarburizing to or toward carburizing with increasing temperature. It seems probable that for each of these mixtures, there is a temperature at which neither decarburization nor carburization would be produced in a steel of the carbon content here dealt with, and that there are other temperatures at which these mixtures would be in equilibrium with steels of different carbon contents. The fourth mixture, containing sodium carbonate, which showed a carburizing action throughout the entire temperature range investigated, would undoubtedly react similarly to the other three, if properly modified by reducing the concentration of its extremely powerful energizer.

The results of the investigation prove that many of the "reducing" or "carburizing" packing materials used to protect steel during heating operations may be and probably often are responsible for the skin softness observed in the steel after heat treatment.

They further suggest the applicability of the charcoal-sodium carbonate mixture as a preventative of decarburization and the soft skin difficulties which result from it. The formation of a shell of massive carbide, noted at the lower temperatures, in the usual hardening and annealing range, might seem objectionable, though we believe it to be negligible. This objection could be obviated, however, by lowering the sodium carbonate concentration until a mixture is obtained which will be neutral to the particular steel which is to be treated, at the required treatment temperature.

This has been demonstrated on tool steel in practical work, with apparent complete satisfaction, using a sodium carbonate concentration of 3 to 5 per cent, but no attempt has been made to determine quantitatively whether the mixtures were really neutral, or still slightly carburizing, or decarburizing.

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11. "Carburizing of Iron by Mixtures of Hydrogen and Methane"—W. P. Sykes, TRANSACTIONS, American Society for Steel Treating, Vol. 12, p. 737.
12. "Gas Carburization of Steel"—Guthrie and Wosazek, TRANSACTIONS, American Society for Steel Treating, Vol. 12, p. 853.

DISCUSSION

Written Discussion: By H. B. Knowlton, metallurgist, International Harvester Company, Fort Wayne, Ind.

The authors are to be congratulated on their valuable contribution to the study of decarburization. Giolitti and others have shown that carburization and decarburization follow the laws of chemical equilibrium, and that the same gas or combination of gases may cause carburizing or decarburizing depending upon the initial carbon content of the steel and other factors such as temperature, pressure and volume of the gases. The paper just presented is in accord with the principles enunciated by Giolitti, but the present authors have gone further in that they have given a practicable remedy for decarburizing at least where pack annealing or pack hardening is feasible.

This paper is valuable not only to tool hardeners but to all who are engaged in any form of heat treating in which decarburization is undesirable. It should be of particular interest to the makers and users of fuel-fired hardening and heat treating furnaces, because it shows that the so-called "reducing" atmosphere (or one containing an excess of unburned gas or oil vapor) does not prevent decarburization. The authors may well be asked for their advice concerning the proper control of the furnace atmosphere. We would also like to ask the authors what information they can give in regard to the effect of steam entering an automatic hardening furnace through the chute to the quenching tank.

It is particularly interesting to note that sodium carbonate is shown to be a more active chemical energizer than barium carbonate in increasing the carburizing action of wood charcoal particularly at the lower temperatures. It is also interesting to note that the carburizing action of this mixture was apparent at a temperature below the critical point. This refutes the statement once made that sodium carbonate and charcoal without other chemicals produced no more carburizing than charcoal alone at temperatures below 1800 degrees Fahr. The statements of the present authors are confirmed by commercial use of charcoal-sodium carbonate mixtures.

While on the subject of sodium carbonate, we would like to ask the authors what they can tell us of the effect of sodium carbonate either in the presence or absence of chlorides, water vapor or other chemicals, upon heat resisting containers and electric heating units.

In closing let us again thank the authors for exploding some of the fallacies concerning decarburization and for offering a practical solution.

Written Discussion: By L. A. Lanning, metallurgist, New Departure Mfg. Co., Bristol, Conn.

The authors of this paper are dealing with a real practical question of considerable importance.

In a great number of cases, probably a large majority, the pieces to be annealed are forged pieces to be finish machined or ground with a considerable amount of stock to be removed. Here a slight decarburization is relatively unimportant. In case of the reworking of tools, annealing, without decarburization, is very important as stock removal may be relatively small in amount.

Annealing of tool steel bars by the mill without decarburizing, enabling the tool maker to use bar stock closer to finished tool size, would eliminate the use of a considerable tonnage of tool steel. A considerable saving in machining time would be possible, which is quite important, as tool room labor is high priced.

I note that the authors, on the second page of their paper, refer to a soft skin on steels heated under reducing conditions. I would like to know whether or not they have checked this for decarburization. I have observed this soft skin on oil-quenched steels in particular where excess fuel is deliberately added. Heating oil hardening steels in an oil-fired furnace with a considerable excess of fuel is very apt to produce white spots on the pieces which are invariably soft. At first thought this appeared to be decarburization, but rehardening these same pieces results in perfect work. My belief is that a deposit forms on parts being heated which retards the effect of the oil quench. This inference is drawn because of the presence of the white spots which indicate freedom from oil scale. I have also seen this same condition on work quenched from gas fires operated with a reducing flame. This may be one source of "soft skin" on work heated under reducing conditions.

The use of special packing material as listed by the authors is an excellent suggestion for guarding against decarburization in annealing. They have brought out very well the action of these materials under varying

conditions. I might add that the commercial carburizers produce about the same result as the sodium or barium charcoal mixtures.

I wish to congratulate the authors of this paper for opening up an important subject and hope that it may stimulate interest in this field which is of such great importance.

Written Discussion: By R. G. Guthrie, metallurgist, People's Gas Light and Coke Company, Chicago.

The authors are to be complimented upon this useful contribution to the subject of carburization and decarburization. I should like to ask one question before proceeding with this short discussion, and that is regarding the moisture content of the various mixtures they tried. We have found that moisture is probably one of the most influential constituents found in carburizing gases, and it would be interesting to know whether these materials all contained exactly the same amount of moisture when the test was started.

As to the decarburization of steel in a so-called carburizing atmosphere, I feel that the entire subject of carburization and decarburization is a relative one, and that almost any gas or combination of gases, or solids and liquids for that matter, may be carburizing or decarburizing at the will of the operator, provided the equilibrium condition of the gas or medium is understood. As an example of this the average city gas, which in its simplest form is a complex system of hydrocarbons, is decidedly a decarburizer when stagnant, but becomes an active carburizer when allowed to flow over the material. Particularly is so-called city gas a decarburizer when it contains any appreciable amount of moisture, and it is a very efficaceous carburizer when it is thoroughly dry.

Practically any condition which upsets the equilibrium existing between the carburizing medium and the steel results in that carburizing medium becoming a decarburizing medium. This is especially true in the case of eutectoid or hypereutectoid steels. It is possible and probable that a medium which under a given set of conditions will decarburize an hypereutectoid steel, will carburize an hypoeutectoid steel at least up to the eutectoid composition. I have noted many times that under normal conditions, with a 0.20 per cent carbon steel, a case depth of about $\frac{1}{32}$ inch usually represents an outer surface of eutectoid composition. With certain types of carburizing gases, and at certain temperatures depending on the moisture content of that gas, the carburization rate will change at about $\frac{1}{32}$ inch case depth, the next $\frac{1}{32}$ inch increase in case depth will not be obtained in an equal time increment but will require up to 2½ times as much time as would be necessary for the first $\frac{1}{32}$ inch.

Consequently the whole subject of carburization is a question of equilibrium. It is probably true that every so-called carburizing gas is capable of decarburizing under certain conditions. We have recently carburized a low carbon molybdenum steel on a time-temperature-gas flow rate to get $\frac{1}{16}$-inch depth and not to exceed 0.90 per cent carbon in the first five-thousandths of the case. The same conditions were then applied to a 0.20 per cent carbon, 1 per cent chromium steel, with the result that

the case depth was the same, but the outer surfaces were highly hypereutectoid. The change in process necessary to get the same results in this latter case as obtained with the molybdenum steel and the original time-temperature-gas flow rate, was to humidify the gas in the case of the chromium steel which caused a decarburizing tendency apparently just sufficient to prevent the formation of excess cementite.

The three most important factors in the carburization or decarburization of a given steel are: temperature, the manner in which the particular steel normally reacts to carburization or decarburization, and the mechanism of the breaking down of the carburizing or decarburizing medium. In addition to these three major factors, a whole array of minor factors present themselves. The temperature is particularly important not alone to the steel, but to the gas according to the manner in which it breaks down, and the temperature which might be best adapted to the steel either in its heat treatment or its carburization, very frequently will be found to be an extremely unfavorable temperature for the carburizing efficiency of a given gas or medium. I think that probably this condition accounts for a great deal of the conflicting information found by the various investigators.

As each phase of this subject is studied and reported on, more and more of the conflicting information is reconciled in the light of better understanding of the fundamental factors governing the equilibrium of gases and solids at high temperatures. As has previously been stated the authors are to be complimented upon their contribution to this particular phase of the subject, and they have undoubtedly added some valuable and useful information to the subject.

Written Discussion: By Henry Wysor, metallurgical engineer, Bethlehem Steel Co., Bethlehem, Pa.

In my opinion, the most interesting thing about this paper is that it calls attention to the important and often disturbing principle of decarburization below the critical temperature and in apparently neutral or even carburizing media. This fact is not so well known as it should be, and consequently, insufficient measures have been taken to prevent surface decarburization.

Scientifically we are at a loss to explain decarburization under the conditions here mentioned because we cannot fully explain cementation from the standpoint of diffusion. In contrast with the well recognized principle of acceleration, carburization has been affected extremely by means of solid carbon (diamond) without the admission of any gas. After an exhaustive study of research data obtained by himself and others, Giolitti concluded that iron and carbon were mutually soluble under carburizing conditions. That might account for diffusion, and carburization and decarburization are explained simply on the basis of equilibrium. The effect of carbon monoxide and other accelerators depends upon nascent carbon, which is released, possibly by catalytic action of iron. If, as Brearly believes, CO is the carrier, then CO should be a constituent of the gas obtained by decarburizing steel in a vacuum or in a neutral at-

mosphere. His experiment of sealing a piece of steel in a steel tube, and carburizing through the wall of the tube, is clever, but it does not prove the point. If CO_2 and C are generated, as indicated in the equations below, CO would be regenerated, and it would react with the iron specimen as soon as it became concentrated and equilibrium was established. The instability of iron carbide would seem to account for the release of carbon at the surface.

$$2CO=CO_2+C$$
$$Fe_3C=3Fe+C$$

In its practical aspects this paper suggests further experiments:—

1.—Does decarburizing of a spring lower its fatigue value?
2.—Why not shorten the time in annealing operations as in tool steel?
3.—The suggestion to use charcoal-sodium carbonate mixture has obvious objections for many industrial operations but offers possibilities in others.

We are indebted to the authors for their constructive work, and trust they will continue with this investigation.

Author's Reply to Discussion—J. J. Curran

Mr. Lanning remarks that the decarburized surface on steel can be easily removed by machining or grinding. We find that a thin skin or decarburization on parts that are to be ground often causes trouble by loading up the wheel.

He also speaks of soft spots as well as total surface decarburization. The soft spots might easily result, as Mr. Lanning suggests, from a surface condition, such as soot on the surface. However, you can get a continuous skin of decarburized material on high carbon parts by annealing in a furnace where there is a large excess of gas, or in an electric furnace, if it is closed tight and there is oil on the work, or where carburizing compound or charcoal is thrown in.

Owing to the fact that Mr. Lanning has never published anything on this subject, we were unable to include a reference to his work in the paper. Some years back, after we had completed this work, Mr. Lanning volunteered some information which showed that he had duplicated these experiments to a great extent, except that he had not investigated it from the micrographic angle. He had annealed high carbon steel in mixtures somewhat similar to these, and after hardening them had tested them with a file. The results bore out very well what we had found.

Mr. Knowlton asks about the danger of excess fuel. I have said that when reducing carbonaceous gases are present in the furnace atmosphere, decarburization may occur. We believe that a neutral or very slightly scaling atmosphere is the best safeguard against decarburization.

Steam entering the furnace from the quenching tank should not decarburize appreciably. It will scale slightly, and when a little scaling does occur, decarburization is usually minimized.

Mr. Knowlton also asks about the effect of sodium carbonate and chloride on containers. Ten per cent of sodium carbonate might cause trouble, due to slagging, if a little sand or clay becomes mixed in with the compound, forming a glassy slag which may stick to the work and cause soft spots.

As to the effect of sodium carbonate on heat-resisting containers, we have observed that fused carbonates and cyanides of sodium and potassium cause rapid deterioration of pure nickel sheet and of nickel alloys. We have had trouble with crucibles and nickel boats used for experiments with these salts.

I believe that Dr. Wysor's three points are very good. First, he speaks of decarburization below the critical range. I believe that Rosenhain has determined there is some absorption and diffusion of carbon below the critical range, therefore we may assume that decarburization may also occur. Our tests show this to be true.

With regard to the danger of low fatigue life in springs, that is something that I think is largely a matter of opinion as yet. The problem is sufficiently important to warrant careful investigation.

Last, he compares annealing above and below the critical point. An ordinary high carbon steel can be annealed to a given softness much more quickly slightly above the critical point than at a temperature slightly below, and the difference in length of time at the slightly higher temperature may save some decarburization.

I have said that the sodium carbonate mixture is not offered by us as a cure-all, but it does seem to have some merits for pack hardening and annealing operations.

Mr. Guthrie asks if the moisture content was the same in all of the mixtures used. We would say that they were identical, having been made up from the same lot of powdered charcoal and stored under identical conditions.

In some of our other tests, using city gas as the surrounding medium, rather than solid carbon mixtures, we have observed that drying the gas produced profound changes in its rate of carburizing low carbon steel. Under otherwise identical conditions, dried gas produced a hypereutectoid case, whereas gas saturated with water vapor produced a thinner case approaching eutectoid in composition. The presence in the retort of solid chemicals also affected the rate of carburization, and the addition of traces of volatile hydrocarbon derivatives actually caused complete decarburization of 0.20 per cent carbon steel.

Our results emphatically corroborate Mr. Guthrie's statements as to the important influence of seemingly minor differences in the composition of city gas on its carburizing and decarburizing properties.

METALLURGICAL PROBLEMS OF TRANSMISSION GEARING

By Ernest F. Davis

Abstract

This paper describes the action of gear teeth in mesh and demonstrates why tooth failures cannot always be attributed to metallurgical defects. A review is given of the various stages in the manufacture of good gears and the attributing elements in the success or failure of the final product. In this is included many items often ignored but actually vital elements in the manufacture of quiet running transmission units. A brief description is also given of the modern furnace installations used in the gear industry and the advantages and disadvantages of different methods for heat treating gears.

GEARS when assembled in a transmission will be either quiet or noisy. When placed in service in an automobile they will wear, break, become steadily noiser or remain quiet and probably outlast the life of the motor car. When a gear breaks in an assembled unit the cause may be due to overload, faulty design, bad steel, defective heat treatment, improper forging practice or perhaps an assembler has dropped a washer or bolt in the gear box during assembly. If a gear wears out rapidly it may be too soft, the transmission misaligned, teeth not fully meshed, of bad contour, overloaded, or the cast iron housing was not cleaned sufficiently and a little nest of foundry sand was left in one of the corners to break loose by vibration and chase merrily around into the bearings and between the gear teeth. Perhaps the car owner has forgotten that a transmission requires occasional lubrication or has been misguided concerning the harmful effects of aluminum soap, graphite, cork and other nostrums foisted on the public for transmission lubrication. One transmission returned to us recently in a bad condition was found filled with a mixture of molasses and graphite.

A paper presented before the tenth annual convention of the society, held in Philadelphia, October 8 to 12, 1928. The author, E. F. Davis, who is a member of the society, is metallurgist with the Warner Gear Co., of Muncie, Ind. Manuscript received June 12, 1928.

But, regardless of what happens to gears, save a long and useful life, the gear metallurgist finds himself involved in nearly every form of gear trouble, and in a defensive position, when gears are noisy, do not wear satisfactorily, or teeth break in service. Tooth breakage today is a comparatively rare occurrence, but, the big problem in gear manufacturing within the plant is the production of quiet running units, and imparting to them longer life in service.

The necessity for heat treating brings into gear processes certain dimensional changes nullifying to a great extent the efforts of the gear cutter toward mechanical precision, and yet, on the other hand, frequently giving him benign assistance in correcting his own errors. But, before discussing the metallurgist's responsibility in the gear industry, it will be essential to first consider tooth curvatures and the operation of teeth in mesh so that we may better understand the fundamentals of gear metallurgy.

Although a tooth outline is a parabolic curve commonly an involute, yet when two gears are rotating together each is laying down a flat plane surface for the other to roll upon. In other words, each is presenting a metallic pavement for the mating member during its moment of work. When an even surface is presented with continuity, a nearly perfect rolling action ensues. Such gears are quiet. To say a gear is quiet is a relative term only, for two gears in mesh always produce some noise. To be quiet, the sound must not assail the audible sense as unpleasant.

If anything interferes with the ideal performance of this mechanical system, and I am speaking in tenths of a thousandth part of an inch, then the teeth must exercise extra energy to overcome this interference by sliding over, or jumping the obstacle. Thus we have through tooth inaccuracies frictional elements to wear gear surfaces, and vibrational elements to make them noisy.

We may compare the action of gears to the driving of a car over a concrete road. Each cement square represents the working area of a driven tooth, and the segment of the tire in contact with each square as a section of the driving teeth. If the surface is flat and continuous the car glides along smoothly. But if the squares are pitched up or down, a gap exists between them, each square is ridged, wavy, rough or consists of a series of rises and dips, then the car's progress is accompanied by much noisy vibration. The

same is true with a gear tooth's journey around the circumference.

To carry this crude analogy a little further, let us assume that our car instead of rolling along is being pulled or pushed with the tires locked. In a mile or two we would find flat spots worn on the tread of the tires; whereas, if the wheels rolled as they should, these same tires would give us 15,000 to 20,000 miles of useful life. We have the same effect in the wear of gear teeth. If excessive slippage occurs, instead of the normal rolling action, destruction of the tooth form rapidly follows. Gears distorted in heat treatment, or cut incorrectly, will wear out faster than those having correct tooth form. Also, a gear of imperfect rolling action cannot be rectified by burnishing, or by any "wearing in" operation any more than a high spot or hole in the road flattens by continuous traffic. Such gears, like the holes in the road, instead of improving, become steadily worse.

Relative hardness is also a factor under these conditions, for softer surfaces will flow and indent under the friction and pressure of slippage more readily than harder ones. A gear of 75 scleroscope hardness, incorrectly generated or distorted, will not wear as well as one of 70 scleroscope having proper tooth form. Of course, when we approach a condition of intense hardness the resistance to wear is such that slippage disintegration is much retarded.

If gears are cut inaccurately no heat treatment will give them satisfactory life, and if heat treated poorly, no perfection of gear cutting methods will produce good gears. Gears may be cut and hardened so that tooth curvatures are perfect and yet not be quiet in mesh due to shaft flexure, mechanical tolerances and other elements peculiar to every individual model. It may thus be seen, that successful gear making involves not only gear cutting and heat treating, but the entire organization of the gear plant.

Gear troubles are nearly always made up of a collection of small errors, and seldom a few big ones. The big ones are obvious and easily corrected, but the small ones are microscopic and difficult to locate. We do not speak of gear inaccuracies in fractional dimensions, but in tenths of a thousandth part of an inch, and many factors, not ordinarily considered as bearing on gear troubles, may be fundamental. Oil viscosities, periodic vibrations, mountings, certain phases of phonetics and acoustics have a relation to

gear noise. Even the state of the weather has an influence, at times, upon the quietude of gears as I shall explain later.

Steel Mill Practice

The making of a good gear begins in the steel mill. The chemistry is of course important. Gear steel is usually bought with a 5 point limit for carbon, and close checking of all elements; following, as a rule, the S. A. E. practices. Dirt, inclusions, and segregation should be as nearly absent as possible, for they affect the movement of metal in the final heat treatment. The ingot mold, the soaking pits, billet furnaces and rolling mills all contribute their share in producing good or bad steel.

Steels Used for Gearing

Two types of steel are employed for transmission gearing; viz, the oil hardening and the carburizing grades. The oil hardening class of steels includes the plain chromium, chromium-vanadium, chromium-nickel and 3½ per cent nickel steels of about 0.50 per cent carbon. Steel above 0.55 per cent carbon is unsuitable for most types of gears, especially, those subjected to sudden shocks and clashing. The balance between safe impact and hardness reaches the maximum at about 0.55 per cent carbon which yields about an 80-foot impact average (drop test) on an 8-10 pitch tooth and a scleroscopic hardness of 72 to 80 with an average of 75. When the carbon is 0.60 per cent only about 2 points is gained in scleroscopic hardness with a decrease of about 20 foot pounds in impact. A 0.70 per cent carbon chromium-vanadium steel gave a hardness average of 82 with only a 35 foot-pound impact. When the tempering temperature is raised to increase impact values to 80 the hardness decreased to 72 scleroscope average, hence, no benefits are found by increasing the carbon beyond the 0.55 per cent maximum.

We find the same range of alloy constituents in the carburizing class but containing approximately 0.20 per cent carbon. In addition, we have 0.5, 1.5 and 5 per cent nickel steels of low carbon content. The nickel steels present a unique series and are very valuable for gears due to their depressed critical points enabling low heat treating temperatures and a milder oil quench, both

factors in reducing distortion. Even the 0.5 per cent nickel steels will harden fully in oil, and the 5 per cent nickel steel is one of the toughest and best wearing gear steels known.

The two most common types of steel in use today by gear makers are the chromium steels of about 0.50 per cent carbon, and 3.5 per cent nickel in the carburizing grade.

Forging Practice

Cold Shearing. When bars are rolled and pass into the cooling beds they lose their residual heat rapidly. If the carbon is around 0.50 per cent considerable hardness is imparted to the steel. The faster these cool, the greater will be this hardness due to arresting the constituents in a partial or complete sorbitic state. During the winter months when the temperature is extremely low this hardness becomes quite high, frequently showing from 302 to 415 Brinell hardness numbers. It is impossible to cold-shear such steel without producing enormous strains in the metal. If the steel is forged immediately the effect may not be injurious, but steel under such strains frequently cracks after a short period. We had one sample which did not crack visibly until three days after it was sheared. Steel cracked in shearing may be upset into forgings and the defect not noticed until the part is being, machined, or worse, not until after the gear is put into service. The usual method adopted by the drop forger is to limit the sizes, say 1½ to 2 inches for cold shearing and hot shearing above these sizes. This decision is usually based on what shearing blades will stand rather than the harm that may be done to the steel.

In the low carbon steels the soft ferrite constituent predominates to such an extent that hardness rarely causes any difficulty. We have no record of any failure from this cause in the 0.20 per cent carbon steels. These steels do not harden materially during the cooling period after rolling except in small sizes or in steels high in alloying elements.

Metal Flow. We have always insisted upon upsetting practice on all gears. We realize that an enormous production of gears has been made from square and slab stock, or forged by methods where the fiber of the original billet has been only slightly disturbed. No doubt many good gears have been made by this

method, and some disagreement exists whether orientation by upsetting is of sufficient value to justify the practice.

Heats of steel show physical vagaries apart from the chemistry. Occasional lots of steel will be found which show a tendency toward considerable permanent growth parallel to the grain flow and very little at right angles to it. Other heats of steel do not show this peculiarity as marked. What metallurgist can know when such a lot of material will be present in production, for nearly all steel is banded to some extent as any macrograph will show! If all gears are upset and these lines dispersed radially, the ill effects are minimized for no "out-of-roundness" can occur from this cause. Inattention to this is one of the obscure causes of gear distortion, which produces noisy gears.

Another important advantage is the greater strength of the upset forging, partially by increased working, and partially by better fiber distribution. Steel is usually 15 to 20 per cent stronger at right angles to the fiber than parallel to it. It is a recognized fact that gears made from bar stock are weaker than the same gear made from an upset hammered forging. The bar stock gear has the fiber lines parallel to the length of the tooth. Gears forged from slab stock have some of the teeth with fiber in this direction and some teeth at right angles to the fiber. But a gear, like a chain, is no stronger than its weakest tooth and the actual tooth strength of such a gear is not much better than the bar stock gears.

To insure ample working and upsetting, the smallest size which may be upset without buckling should be specified. Sheared ends should be square so that the upsetting action is equalized.

Forging Temperature. The necessity for better control of forging temperatures is steadily becoming more urgent, and the forging operation has long been a prolific source of metallurgical troubles of all kinds.

The ideal temperature for forging gears is the minimum heat which will produce a good forging properly filled so that it will finish at 1600 to 1700 degrees Fahr. If a forging is heated to 2200 degrees Fahr. and finished at 2000 degrees Fahr. it will be coarse-grained and overheated. If it is forged at 2300 degrees Fahr. and finished at 1600 degrees Fahr. a good forging will result. The less work there is on a gear forging, the lower the temperature

should be for forging, but nearly all forging can be done between 1800 and 2200 degrees Fahr. with an average heat of 2000 degrees Fahr.

Fast heats, but freely oxidizing are best to prevent decarburizing, for the scaling rate must be faster than the carbon migration.

Normalizing of Forgings

In any lot of forgings considerable variation exists. Some have been forged hot, some comparatively cold, some have cooled faster than others, some have finished hot, some perhaps have been overheated, and others finished at a low temperature. The microstructure having been disturbed by heat, hammering, metal flow and different cooling rates is in a more or less conglomerate condition. Since each forging has received individual treatment and has been subjected to certain variables, it is natural to assume that these would not respond alike to any single heating and cooling cycle. Forgings subjected to heavy working and finished near the critical temperatures do not readily anneal and ordinary annealing methods cause these to emerge from this operation in a semi-sorbitic condition unfavorable to good machining. Those which are coarsened by high heats and little working likewise respond sluggishly to thermal treatment. A large percentage of a lot may anneal satisfactorily, but we cannot segregate those which do not. However, if these are given a preliminary high temperature treatment it enables better solution of the micro-constituents and overcomes to a great extent the slow response of coarsened metal. It also equalizes the grain size of sections given much working and sections receiving very little upsetting and hammering, a matter of great importance in minimizing distortion in the final gear.

For both oil hardening and carburizing grades the temperature of normalizing we employ is 1750 degrees Fahr. followed by a rapid cooling in air. This practice may seem of dubious value for higher carbon steels, with danger of decarburizing, too great coarsening of structure and an ultimate weakening of gear teeth. Actually none of these things occur. The short period in the furnace decarburizes the forging only a few thousandths, and the time at heat is too short to cause any marked migration of carbon. Our impact values on gear teeth has improved and become more

consistently uniform and the coarse, dry fracture indicative of weak brittle teeth has practically disappeared since this treatment was inaugurated. The uniformity of annealing results may partly, at least, be attributed to this preliminary treatment.

In the carburizing grades of steel the normalizing is prolonged and the cooling is sufficiently slow to actually coarsen the ferrite. In this case the object is to relieve the steel from all internal strains so that no movement will occur in the subsequent carburizing operation. The coarsening of the ferrite is an aid to machinability, for coarsened ferrite machines better than fine-grained ferrite. The best illustration of this effect is shown in the records of our bevel gear department where cutter life was practically doubled after the inauguration of this treatment. Another marked effect was reduction of "out-of-roundness" and "out-of-flatness." On some models, the straightening operation of ring gears has been entirely eliminated. In the transmission gears we found less trouble with shrinkage of holes and less diameter changes.

Annealing of Oil Hardening Steel

Considerable research work has been done by us to obtain the best microstructure which would yield good machining results and a smooth finish on gear teeth. For our particular steel we have found a lamellar pearlitic structure is best adapted for oil operations.

The important thing in annealing is to have all the forgings of the same general microscopic pattern. Variations in strength, hardness and toughness of gear blanks produce a difference in cutting results. If a gear blank is hard (sorbitic) more resistance to cutting occurs and the gear cutters will not hold their edge, dull rapidly and sometimes peel and cause ridges on the tooth surfaces. If a gear blank is too soft it cuts roughly and accurate checking of the involute is difficult. One may readily realize the baffling situation for the gear checker when hard gears, soft gears, and gears with a variety of structures are present in the same lot of blanks.

To be assured of uniformity, furnaces for annealing must be designed so that the desired structure can be obtained with certainty, and each forging subjected to the same heating and cooling cycle.

It is obviously impossible to obtain such results in any stationary furnace of sufficient size to handle forgings in production quantities. The heating and cooling rate is not under control when forgings are annealed en masse. Those on the outside of the pile heat and cool with greater rapidity than those on the interior.

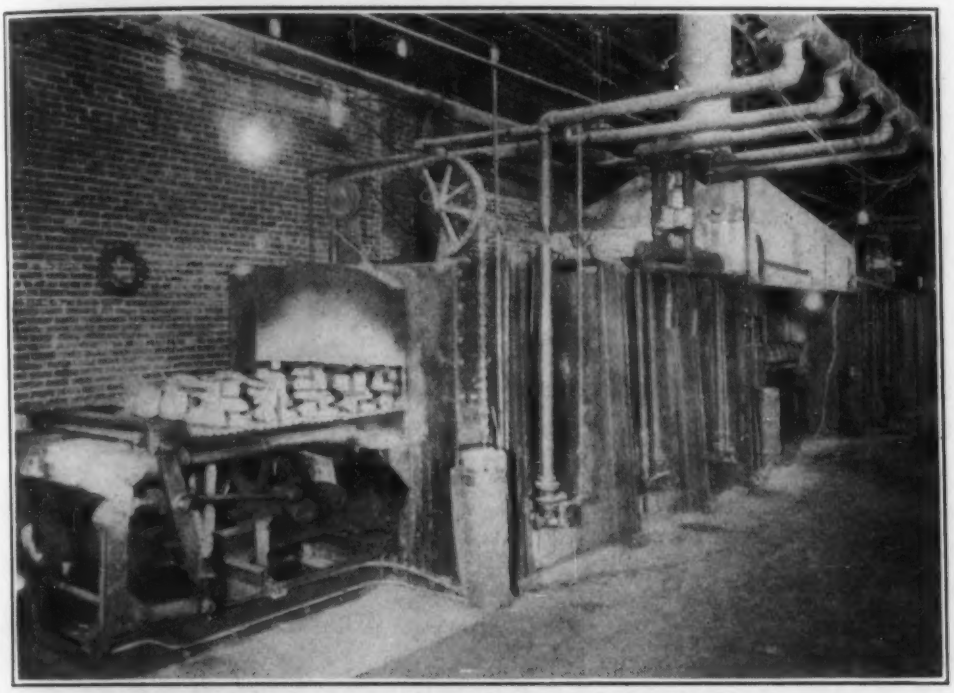

Fig. 1—Combination Normalizing and Annealing Furnace Train. The First Furnace is for Normalizing and the Second for Annealing. Note Open Gap Between Furnaces for Air Quenching of Forgings After Normalizing.

The ideal way is to have the forgings pass through a series of heating and cooling zones maintained uniformly by automatic pushing and fuel control so that a definite mass of metal absorbs and loses a certain amount of heat per foot of travel. By changing the speed of travel, or the temperature of any zone, any kind of structure may be obtained, and when the best machining structure is found, the matter of duplication is as certain as any mechanical operation. (Fig. 1)

Among the vital items in maintaining these results is regulating the weights of forgings per tray. In our continuous furnaces the trays are three feet long and one foot wide and each carries 350 pounds of forgings regardless of the shape or the mass of the individual forging. In our various models are gear forgings of

weights from 10 ounces to 35 pounds, but the number per tray is computed so that the total weight will be 350 pounds. This permits steady burner action and the same microstructure is obtained in both the largest and smallest forging.

Annealing of Low Carbon Gear Steel

The annealing of low carbon steel does not offer the problems of the oil hardening grade. A normalize and an anneal at 1500 degrees Fahr. with an air cool usually places this steel in the best machining state. Over annealing and very slow cooling is apt to produce a tough stringy condition not suitable for smooth finishing.

Carburizing Practice

Much prejudice exists against the carburized gear, from a gear maker's standpoint, although the combination of hard surface and the tough ductile backing of the low carbon core makes an ideal tooth for high impact, wear and strength. In fact, truck transmissions which are subjected to heavy tooth load and much abuse are still made of carburized steel and substitution of oil hardening grades has seldom given satisfactory life. In pleasure cars, where quiet running gears is paramount, the oil hardening steel predominates. In the past, no certainty has existed as to just which way the cat would jump in regard to distortion and volume changes, and carburized gears have always been the source of much trouble to gear manufacturers in maintaining high standards for quality.

In addition, the carburizing operation has always been an expensive one, costing, usually, from 8 to 12 cents per pound. When oil hardening steels were introduced, capable of giving scleroscopic hardness of between 70 and 80 without excessive brittleness, the gear makers found not only relief from high manufacturing costs, but gear rejections were immediately lowered. We had on one model wherein rejections for noise on the test stands dropped from a 20 per cent average for carburized gears to less than a 5 per cent with the oil hardening gears, and the transmissions all had a more even tone.

Other reasons for carburized gear distortion aside from high temperature treatment may be included, the lack of normalizing treatment with low carbon steels, indifferent annealing (and some-

times none at all), and most of all the crudity of carburizing practice. In plants where gears were carburized the furnaces were nearly always of the box-type usually hand-controlled and the maintenance of heats dependent upon the alertness of the furnace operator—who often was not alert. Thermocouples gave the tem-

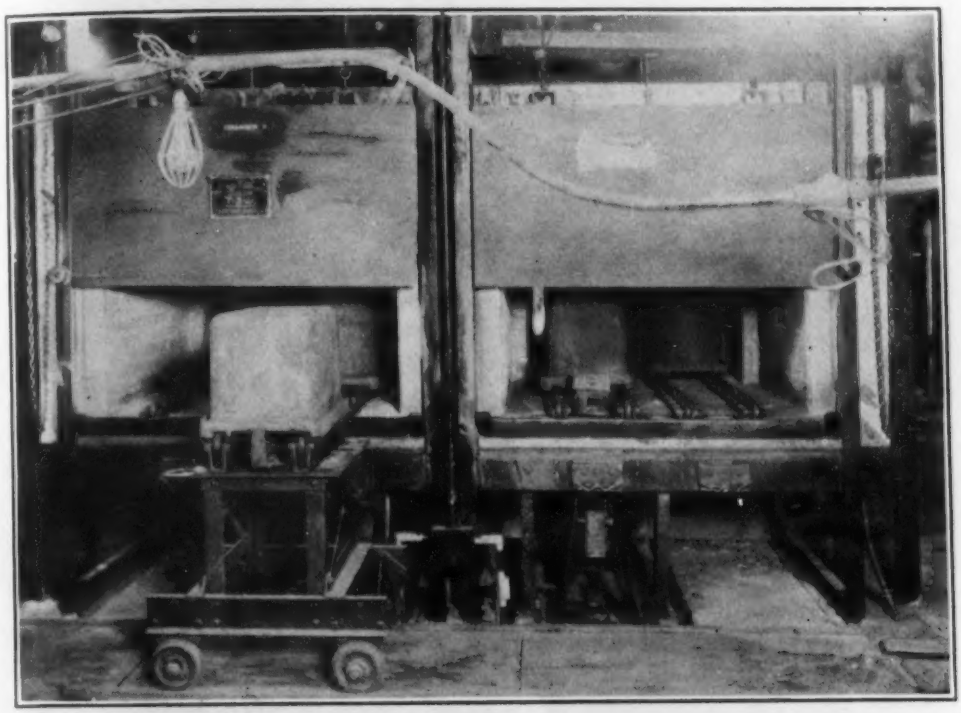

Fig. 2—Front View of Return Recuperative Type Carburizing Furnace. Used for Carburizing Gears. This Furnace is Electrically Heated and Automatically Controlled.

perature of the furnace blast but no indication of what was transpiring within the boxes. Tests made by our laboratory indicated variations of 200 degrees Fahr. in a single heat in different locations of the furnace. Carburizing in box furnaces is a blissful optimism.

Metallurgists have long been aware of the shortcomings of the stationary furnace but until a few years ago no better equipment was available. Today much improvement has been made in this operation. The latest type is the continuous furnace. In this kind of furnace, boxes of standardized size are pushed through zones of fixed temperature which is automatically controlled. By regulating the speed of pushing, any desired depth of case may be obtained accurately within 0.005 inch. Although variations in

case depth do not produce differences in volume growth, yet differences in temperature of carburizing do cause enough variations to produce gear trouble.

Three types of furnaces are in use at present, the rotary, the straight through, and the counterflow. The last type utilizes

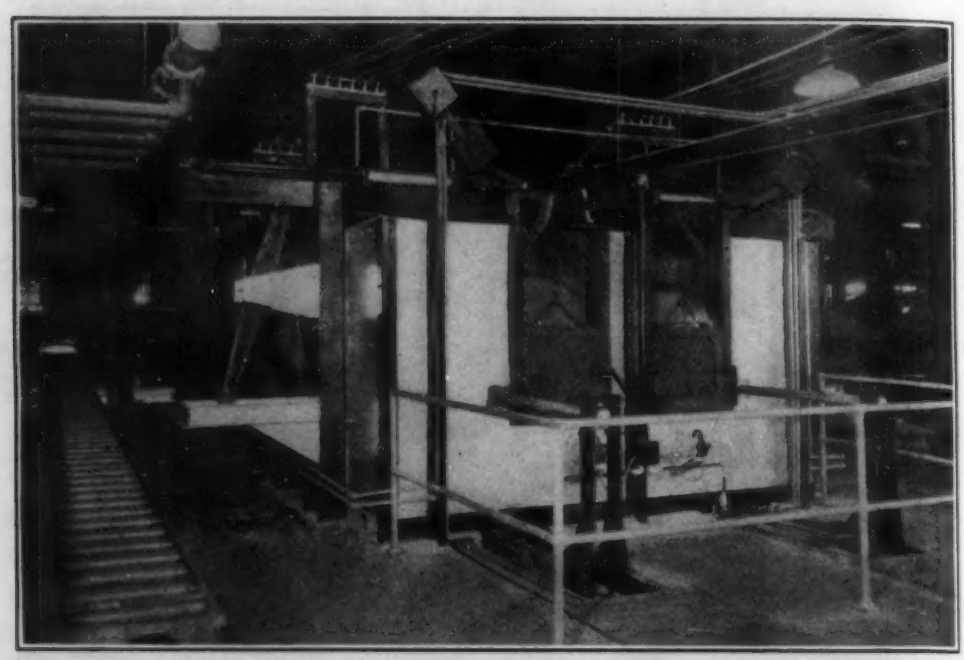

Fig. 3—Back View of Return Recuperative Carburizing Furnace Showing Rear and Side Pushers.

the radiant heat from the outcoming boxes to preheat those just entering. This furnace is suitable only for gears to be cooled in the boxes. (Figs. 2 and 3)

For metallurgical quality, quenching from the box is the best practice, but not a good procedure for gear dimensions and would ruin almost any gear from the standpoint of quiet operation. For that reason quenching from the boxes is seldom indulged in unless the factor of safety is low and the best metallurgical treatment is necessary, a high standard of gear quietness is not essential, or the tooth form is corrected by grinding after hardening.

No doubt, with our improved knowledge of gear cutting, normalizing and annealing, better made steels and with the carburizing operation under exact control, the carburized gear will come into its own again for pleasure car transmissions.

Fig. 4—Cross-Section of Gear Tooth Showing Overheating and Insufficient Working. Fig. 5—Photograph Showing Tooth Pitting Due to Excessive Slippage.

Hardening of Gears

A gear generated by modern gear cutting methods is a marvel of mechanical accuracy. If this gear should change its tooth contour in heat treatment so that it developed an involute error of

Fig. 6—Illustration Showing the Mechanics of Tooth Destruction.

0.0005 inch, it is likely that such a gear would chatter or be too noisy to pass test.

It may thus be realized that gear hardening becomes a process even superior to the finest tool hardening, for there are few tools which do not receive some form of corrective grinding, whereas a gear is expected to come from heat treatment with its original dimensions unchanged.

Yet, in the operation of hardening, the gear expands, passes through the phenomena of contraction at the critical temperatures and then expands again above it until at the moment of quenching it has become a soft plastic body with low strength and its original dimensions altered. Then while in this hot enlarged condition it is suddenly plunged into oil and rapidly contracted. The structure, by the heating and drastic cooling has been converted into new and harder bodies of different molecular arrangement, which did not exist when the gear tooth was generated. In addition to

the changes within the mass, the surface has been exposed to oxidation and other active chemical influences from furnace gases. Yet in spite of all these internal and external agencies, apparently ruinous to accuracy, gears are hardened in production by the thousands every day developing involute errors seldom over 0.0004 inch.

All the common methods for hardening steel are employed in the heat treatment of gears. Immersion hardening in lead and salt baths is quite common. Also processes with pot, box and continuous furnaces using gas, oil or electricity. Each method has certain advantages and disadvantages and no one is ideal.

It is the general opinion that steel must be slowly heated or distortion may result. This may be true when hardening heavy masses of metal or steel of low heat conductivity, but is by no means true as far as gears are concerned. Just as good gears may be hardened by a 10-minute immersion in molten lead, as in a 1½-hour soak in a pot or box furnace. But, it is important that a gear be uniformly heated and uniformly cooled and be so designed that extreme thick and thin sections are avoided. Lack of consideration by the gear engineer to the design has caused much heat treating trouble attributed entirely to the hardening.

The Hump furnace method, if properly handled and intelligently supervised, is one of the best processes for hardening gears in use today, but if carelessly done and blind dependence placed on chart reading, it is one of the worst. When one considers that motors, dry batteries, potentiometers, and potentiometer balancing, gearing rheostats, coils, ammeters, ink, paper, resistance units, and a lot of electrical, metallurgical, and mechanical attention is necessary to keep a battery of Hump furnace units functioning correctly, it may be realized that production hardening by this process may be subject to many variables unless all parts are operating correctly. And even when such is the case, if the work is not proportioned right, the heating cycle may be very non-uniform in various gears. For example, if the bottom of the furnace were loaded heavily with gears, but none in the upper area of the furnace, these gears on the top of the nest would heat much faster than those on the bottom, yet the chart readings would show the critical of the bottom gears only. Also, if the lower areas of the furnace were charged with a greater mass of

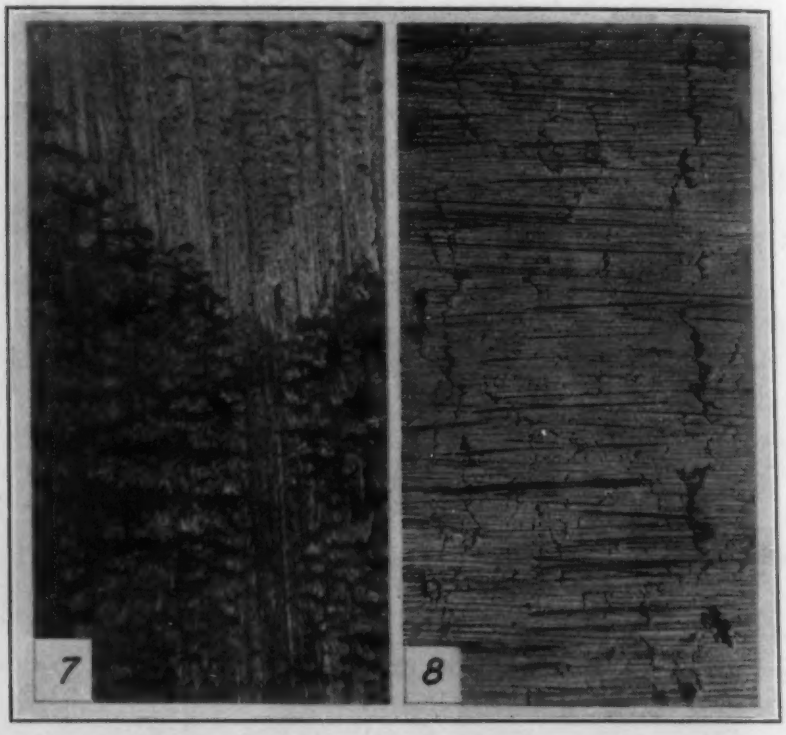

Fig. 7—Photograph Showing Hobbed Surface of Gear Tooth. Note Tearing of Surface. Fig. 8—Photograph Showing Tearing of Overstrained Surface of Gear Tooth Due to Excessive Burnishing.

metal than the upper areas or the situation reversed, unequal heating would follow. In the first instance those on top would be overheated and in the second instance those on top would be underheated if one depended solely on the chart readings to determine the quenching time. Other causes for variables are the employment of a furnace too large for the work to be treated, and overloading and forcing the furnaces to yield a greater tonnage than they are capable of doing.

But the Hump furnace combines many advantageous features. Lack of blasts, low oxidation, uniform heating rates and definite record of every heating cycle. Although far from ideal as a production furnace this method is one of our most scientific developments in heat treating.

Cyanide Hardening of Gears. The necessity for harder surfaces than the oil hardening steel is capable of giving has caused many gear makers to go to some process of cyaniding the surface. This enables the gear maker to still employ the oil hardening steel

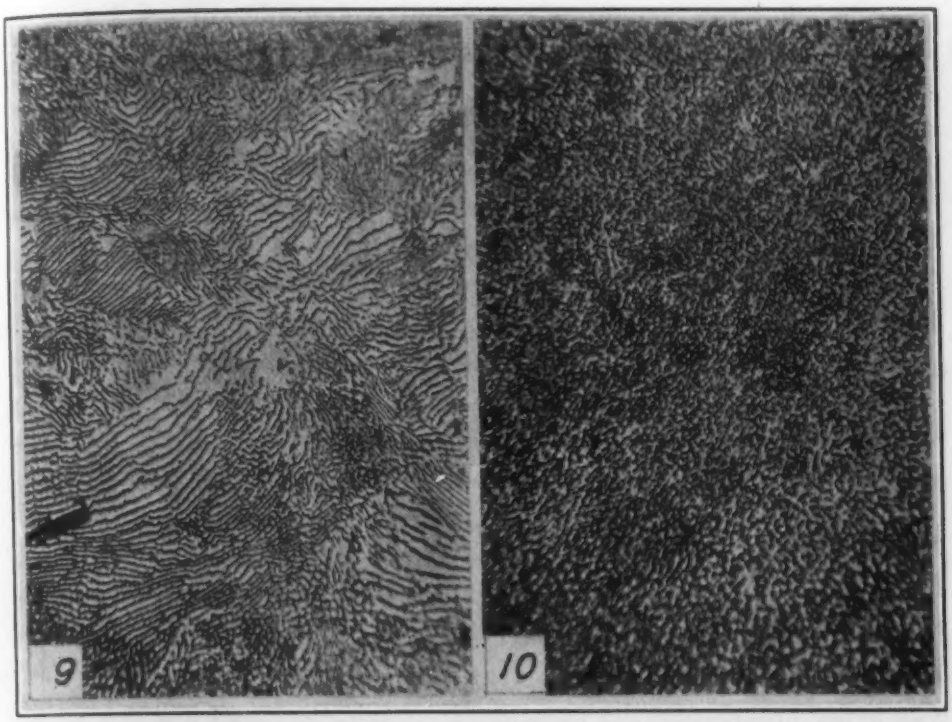

Fig. 9—Photomicrograph Showing Lamellar Pearlite in a 0.50 Per Cent Carbon Chromium Steel. Brinell Hardness 196. Fig. 10—Photomicrograph Showing Granular Pearlite in a 0.50 Per Cent Carbon Chromium Steel. Brinell Hardness 196.

and yet avoid the expensive carburizing method and its attendant troubles.

There are three variations of the cyanide method. The first is direct immersion; the second preheating to 900 to 1100 degrees Fahr. and completing the cycle in cyanide; the third is the cyanide dip after finishing the heating cycle in rotary or Hump furnaces.

Oil hardening steels as a rule increase slightly in volume in heat treatment and if the entire heating is done in cyanide or after a preheat below the active oxidizing temperatures, this volume increase shows a tendency to minutely change the tooth contour to what gear makers call the plus side. This small deviation from the true involute aids considerably in producing quiet running units with some types of driving gears. Certain other gears would not operate quietly on the plus side hence direct cyaniding under such circumstances is not an advisable procedure.

If, instead of direct cyaniding, the gears are heated in a Hump, rotary or other type of furnace to the hardening tempera-

ture and before quenching are given a cyanide dip of 1 to 1½ minutes, we obtain all the advantages of the cyanide plus the reduction in diameter due to oxidation in the furnace. The oxidation loss may represent 0.002 to 0.0025 inch from the diameter thus compensating for the normal volume increase of the steel in heat treatment. This method of cyaniding is, therefore, the best for maintaining the minimum volume change.

Many believe that cyanided gears are noisier than oil-hardened gears. This may or may not be true. Mars and bumps on cyanided gear teeth do not come off as readily as those on furnace-hardened gears and these are, of course, bad noise producers. But with a full understanding of the fundamentals surrounding the cyanide process there is no reason why the mere fact that the cyanide surface is harder should be the basic cause for noise.

To illustrate, we changed a model from a Hump furnace hardening operation to a direct cyanide treatment. The first gears hardened were extremely noisy. Had we stopped there we might have convinced ourselves that cyanided surfaces meant noisy gears. But after modifying the treatment so that we obtained the benefits of oxidation by a combined furnace heating and cyanide dip, the job went along in excellent shape. Rejections actually declined 3 to 4 per cent until the termination of this model.

Sometimes it is the practice to cyanide only certain gears of a unit so that furnace hardening gears mate with cyanided gears. Under these conditions the former will wear better than if meshed with an oil hardening gear. Destruction of tooth form is a mutual operation between mating gears, hence if one has an extremely hard surface it seems to prevent the development of wear in the other. Our dynamometer tests indicate about 30 per cent better life under these conditions.

Cyaniding, however, has a tendency to somewhat lower impact values, and is not recommended for fine pitched teeth or teeth stressed close to the safety limit. It is the practice in some gear plants to lower the average carbon content of oil hardening steels 3 to 5 points when cyaniding is practiced to improve the impact.

Lead Pot Hardening. This is employed for carburized gears more frequently than for the oil hardening types. Owing to the high heat conductivity and rapid heat transfer, lead hardening is one of the best methods for certain types of gearing such as stem

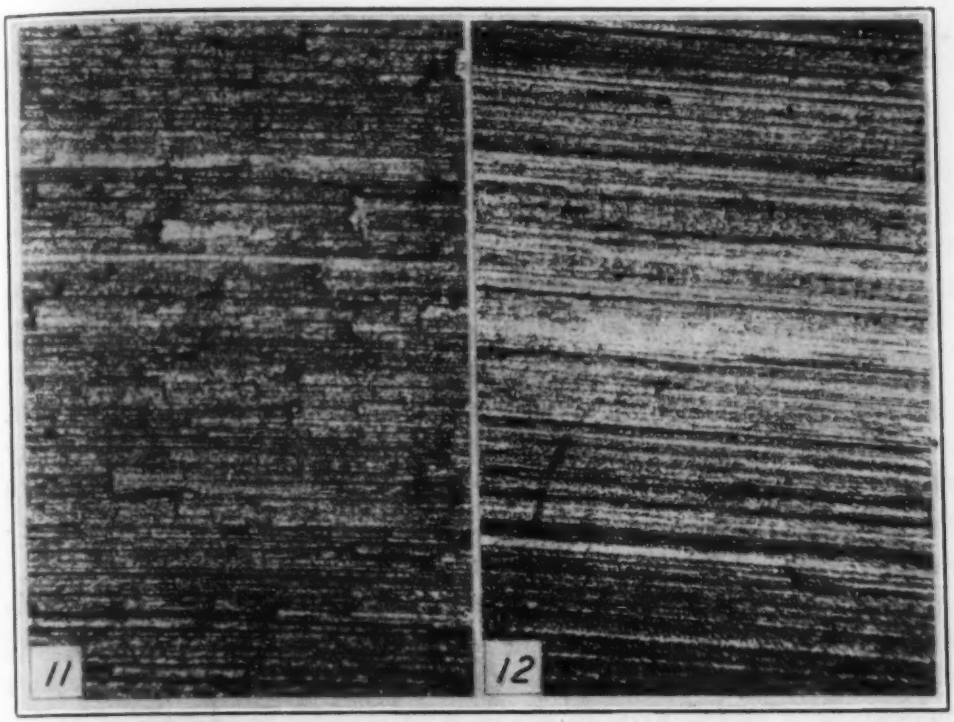

Fig. 11—Photograph Showing Smooth Cutting Gear Surfaces. The Structure is Lamellar Pearlite. (See Fig. 9.) Fig. 12—Photograph Showing Roughly Cut Gear Surface. The Structure is Granular Pearlite. (See Fig. 10.)

gears and pinions. But, like all other processes, it has certain objectionable features and some prejudice exists against its rapidity of heating. One of the worst troubles experienced in lead hardening is the removal of the lead, which frequently clings to the surface and is often difficult to take off. Also, if the lead is impure, decarburizing occurs at times producing poor wearing surfaces. Lead is heavier than steel, thus necessitating special fixtures to keep the gears fully immersed.

Hardening of Carburized Steel. The double heat treatment of gears is always advisable from a metallurgical standpoint, because it produces the maximum tooth strength and ductility. If 3.5 per cent nickel steel is employed, the core refining heats can be kept at a fairly low temperature not much above the hardening heat of the oil hardening steels, but if chromium-vanadium or chromium-nickel steels are to be heat treated this requires high refining heats of between 1550 and 1650 degrees Fahr. Such temperatures are the bane of the gear cutter by causing abnormal metal movement.

The tendency among gear metallurgists is to eliminate the high quench and slightly raise the case refining heat and obtain a partial core refinement at the expense of the case. This method, which is a compromise to aid the gear cutter, has been fairly successful because it does minimize to some extent the distortion resulting from the double treatment.

Quenching of Gears. The quenching of gears is as important as the heating. A gear consisting of extremely thick and thin sections may be heated with the utmost care and uniformity but on quenching, the thin areas will cool to rigidity first, placing strains in the metal and thus causing distortion. This is, of course, a matter of unfavorable design for the heat treater. The only way such distortion may be overcome is by the use of rings and fixtures to falsely thicken up the sections which chill, or by milder quenching at the expense of the hardness.

In production hardening, mechanical quenching of gears is the usual practice, partly for labor economy and partly so that each will receive the same quenching action. Some of these devices consist of a rocker arm on the ends of which are suspended hooks. Others consist of long rods connected with an overhead crank. The movement of the crank gives an up and down motion to the rods. In either type the nests of gears on removal from the furnace are hung on the hooks and quenched in the oil at a rate of about 20 strokes per minute.

Quenching Oils

The purpose of a quenching oil is solely to remove the heat from the steel. Various quenching oils on the market show some differences in quenching rate. Usually the cheaper oils such as the 28-degree paraffines are suitable for gear quenching. This, however, being a residual oil is often imperfectly refined and liable to be highly acid or contain considerable water. Water is immediately discerned by excessive foaming and a muddy appearance to the oil. Water in oil causes soft spots, distortion and sometimes cracking.

We have found our oil quenches gears best between 100 and 135 degrees Fahr. When the oil is 145 degrees Fahr. or over, an average loss of 1 point in scleroscope was noted. Too much re-

frigeration of quenching oil is also not advisable. When this oil is extremely cold (below 65 degrees Fahr.) we lose about 2 points in scleroscope.

Tempering of Gears

The tempering of gears does not develop any marked volumetric changes, but it does produce vital structural changes in the higher carbon steels. Tempering of oil-hardened steels is usually done at temperatures ranging from 400 to 475 degrees Fahr. This raises the impact value up at the expense of 2 to 3 points in scleroscope hardness.

Three things are important in gear tempering; viz, the certainty that the tempering operation is performed, that sufficient time is allowed, and that every gear is given exactly the same temperature. The first is a matter of departmental supervision, the second and third a matter of the proper equipment and systematized operation.

Gear tempering is done in air, oil, or salts. Most air tempering furnaces are unsatisfactory due to irregularities in the air currents. This is especially true of air furnaces tempering by radiation, but even some of those using convection currents do not yield expected results. I understand, however, that one furnace of recent development has overcome many of the objectionable features of the air tempering principle.

The writer prefers the immersion method of tempering for then the part is surrounded by a definitely heated mobile medium. In our practice oil is used in a circular bath electrically heated and automatically controlled. A large bull wheel rotates slowly over the bath making a complete cycle in 38 minutes for oil hardening steel and 28 minutes for the carburized steels. The gears are hung by hooks on the rim of the wheel. The oil is agitated by means of a rotating propeller screw which keeps the oil in continual circulation and holds the bath uniform within 5 degrees plus or minus.

Miscellaneous Causes of Defective Gears

In Hump furnace hardening when the humidity of the air reaches 55 to 60 per cent saturation, it affects the furnace atmosphere causing a peculiar attack on the tooth surface known as pit-

ting. Steam from washing kettles in the vicinity of Hump furnaces, charging gears wet with cutting compound or water also contributes to this condition. This pitting is really a local decarburization. Such gears are invariably noisy and poor in wearing quality. Bits of charcoal in the furnaces usually overcomes this trouble.

Some types of electrical furnaces produce a closely adhering scale due to changes in the chemical composition of the oxides formed. This brushes off only with the greatest difficulty. Gears having this form of oxide are usually noisy. Copper plating or acid dipping are sometimes resorted to, to prevent this. Gears of the oil hardening grade plated with copper are not quite as hard as those not plated. Acid dipping must be done with the greatest caution for any attack on the surface may ruin the tooth form.

Over burnishing of gears results in overstrained tooth surfaces and causes abnormal crystalline development at points where the burnishing strains are greatest. This growth is actually very minute but often enough to destroy the accuracy of tooth form. The fundamental purpose of burnishing is to remove roughness caused by cutting. Heavy burnishing to alter tooth form is always bad practice.

Conclusion

The author has touched only a few of the steps necessary in the manufacture of a good gear and this paper deals chiefly with the metallurgy phases. Success in the heat treating of gears is dependent upon knowing what to do and always doing the same thing in the same way. We have found that whenever we substitute a mechanical heat treating operation for a manual one and eliminate human variables, we have improved our practice, which has always reflected in lower gear rejections, longer tool life or less manufacturing costs. Yet, the subject is greater than a mere question of heat treatment, for the production of high quality gearing requires intelligent engineering, up to date mechanical equipment and good plant organization. In every gear plant, the engineering, inspection, gear cutting, and metallurgical departments are so closely allied in all gear troubles that only by unselfish cooperation of these branches can gear problems be solved and that ultimate of the gear maker finally be attained—absolute quietude.

DISCUSSION

Written Discussion: By M. J. MacKenzie, Interstate Iron and Steel Company, Chicago.

I want to take this opportunity to congratulate Mr. Davis on his splendid paper on "Metallurgical Problems of Transmission Gearing". He has treated a difficult subject in a very clear, convincing way.

There are several things mentioned on which I should like to ask for Mr. Davis' further opinion.

Under the heading, "Steel Mill Practice", I should like to know if Mr. Davis does not consider cleanliness as important as regards the dynamic strength of the steel as he does its influence on distortion. It has been my experience that it is just as important from this standpoint.

Under the heading, "Forging Practice—Cold Shearing", Mr. Davis points out the dangers of cracking steels of gear analysis by shearing cold. I agree with him that there is always this danger, whether the outside temperature is hot or cold. Gear steel analyses are air hardening and should be hot sheared. This applies to bars which have been finished at the proper temperature and cooled, as we know from experience that they should be, as well as to those bars which are hard, due to some irregularity in the steel mill practice. A few hundred degrees of heat in the bars are all that are necessary for cold shearing. I would appreciate Mr. Davis' comments.

Under the heading, "Forging Practice—Metal Flow", I do not fully understand what Mr. Davis means by his statement that heats of steel show physical vagaries apart from the chemistry and explains this on the theory of the direction of grain growth. I should appreciate more details.

Mr. Davis' last sentence, under "Forging Practice—Forging Temperature", about the best way to prevent decarburizing is very interesting and I believe we would all be interested in more details.

Written Discussion: By E. W. Pierce, Chrysler Corporation, New Castle Plant.

Transmission gearing and all relating factors concerning it requires a comprehensive study. Mr. Davis has covered the gear situation quite well and has given us some interesting information.

A wide study of the oil hardening steels will show that nearly all of the various analyses listed are being used by various manufacturers. It is also quite interesting to note that where two or more manufacturers use the same analysis there is a different method of processing. Different annealing cycles and temperatures are used, some depending on a given heat treatment, others hardness, still others, structures; and then in addition there is a difference of opinion as to what is the proper structure for best machining and resultant hardening. In addition to the several structures mentioned by Mr. Davis, it is known that some prefer a spheroidized cementite. The oil hardening gear steels are also checked by the McQuaid-Ehn test, grading them as to grain size, as an indication of performance

in processing. A more definite study should be made, giving the characteristics of each individual analysis for best enlightenment.

Uniformity of operation from the making of the steel until the gear is finished must be the aim. As pointed out in Mr. Davis' paper, it is the slight variations which cause the trouble.

In the annealing operation it is the writer's opinion that the compactness with which the gears are placed on the trays is the determining factor, rather than weight. Sufficient air circulation must be allowed for, to give uniform and even heating and cooling.

When it is realized that a gear steel must first be low in cost to make it of production value, and then be so handled in its processing that after subsequent hardening there is a minimum of distortion, comparable to, and, in fact, better than, the much more expensive tool steels, it can be understood just what the requirements are. In our production, variations from involute are measured in tenths of thousands, making a very exacting requirement.

Cyanide hardening produces a very good wearing surface, whether it is a full treatment or only a cyanide wash from an electric furnace. Impact values are less with the full cyanide treatment, but it has been our experience that heating in a Hump furnace with a cyanide wash give best impact values. With proper design, however, impact values are of secondary importance with wearing qualities much more preferred. Better wearing is accomplished by running a cyanide gear with a Hump or electric furnace gear.

Written Discussion: By S. A. Richardson, Interstate Iron and Steel Company, South Chicago Works.

It appears to the writer that Mr. Davis' paper, "Metallurgical Problems of Transmission Gearing", is a contribution in a real sense to the general knowledge of this important subject. The facts set forth obviously represent the mature experience of an up-to-date manufacturing organization. In many plants where the management is not so keenly alive to the possibilities of technical co-operation some of the items recorded in this paper are jealously guarded "trade secrets".

It is the observation of an outsider that the production of automobile gears that run quietly enough to satisfy the modern closed car trade involves many unique problems in closely controlled annealing, specialized machinability, and distortionless hardening operations. The kind of machinability demanded for the best results with the various machine tools used in a gear plant is not the same. It appears, for instance, that the microstructure that would permit of maximum production in the lathe operations would be likely to produce stringy or ragged surfaces on the gear teeth in the gear shaper operations. To keep the plant operating smoothly it is, therefore, necessary for the metallurgist to strike a balance between these requirements. Mr. Davis has illustrated this generally desired microstructure in Fig. 9.

In his interesting discussion of carburizing gear steels, Mr. Davis has mentioned the modern tendency to eliminate the high temperature or core

refining treatment. The omission of this treatment favors decrease in decarburization and distortion—both factors of grave importance to the gear manufacturer. In this connection it may be interesting to consider the following average physical properties of S.A.E. 2315 and 2512 steel core stock after treatment with and without core refinement. The test pieces were subjected to a carburizing treatment for 10 hours at 1675 degrees Fahr. without carburizing compound in the box, cooled in the box, and then treated as shown.

S.A.E. 2315 Steel

Tensile Strength	Yield Point	Reduction of Area	Elongation
Reheated to 1550 degrees Fahr., oil-quenched, then heated to 1380 degrees Fahr., oil-quenched.			
81,000	53,400	72 per cent	32 per cent
Single treatment. 1425 degrees Fahr., quenched in oil.			
84,400	62,000	69.5 per cent	27 per cent

S.A.E. 2512 Steel

Tensile Strength	Yield Point	Reduction of Area	Elongation
Reheated to 1550 degrees Fahr., oil-quenched, then heated to 1350 degrees Fahr., oil-quenched.			
101,750	86,200	65 per cent	22 per cent
Single treatment. 1425 degrees Fahr., quenched in oil.			
100,200	86,000	65 per cent	23 per cent

In view of the fact that the case of a gear is considered to be no stronger or no more resistant to crushing than is the core which supports it, there appears much to be said in favor of the single treatment. This would appear particularly to be true when the carbon of the core is on the low side of the usual range.

Mr. Davis has mentioned the steel manufacturer's part in producing good transmission gears. The alloy steel manufacturers recognize their responsibility. They have devoted much study and research to the production of the high quality steel needed to meet the severe requirements of the automotive industry. Mr. Davis mentions various types of continuous and automatic furnaces which, when set, will produce gears day after day that will meet a very narrow and drastic specification. Alloy steel makers through the uniformity and quality of their product have made possible this highly efficient and economical mass production of the parts that make up the modern light weight high speed automobile.

Written Discussion: By Henry Wysor, metallurgical engineer, Bethlehem Steel Company, Bethlehem, Pa.

It has been my privilege to witness operations at Warner Gear before and since the installation of the continuous furnaces. I feel that Mr. Davis is very generous in presenting so much useful information, representing many years of research, and is too modest in his claims with respect to the part he has played in bringing a tedious process to so high a state

of perfection. The principle of repeated heating and cooling has long been known as an effective means for treating steel to minimize distortion in the final treatment. It is a real triumph in the art of industrial gearing to combine this principle with production and control.

The comfort and utility of the motor car are very largely involved with inherent and obscure properties of steel. The steel man is, therefore, concerned not only from a selfish, personal standpoint with such problems as quiet serviceable gears, but he is by position obligated to assist in every possible way towards the solution of such difficult problems.

As Mr. Davis has shown, gear noise is, to a large extent, due to distortion of the steel and he has described the refinements which have been employed in treatments to minimize distortion.

It is difficult to specify the properties required in steel with respect to distortion, but desirable conditions can be produced and, to a certain extent, controlled at the steel works. Freedom from inclusions and homogeneity contribute very largely to the end desired. Inclusions may be found in any grade of steel. As such they may be harmless, but when in excessive amounts and associated with concentrations of ferrite they become bad actors. Regular small-sized crystal grains are desirable and there should be as even a distribution of carbide within the grains as well as throughout the mass. The so-called normality classification serves a good purpose when there is perfect understanding between the vendor and the fabricator of the steel. Adherence to any such plan requires special practice at the open-hearth and a certain amount of selection in the allocation of the product with the attendant penalty on manufacture. It is necessary to have an outlet for off-grade material when these refinements are supplied.

Another thing of great importance in the manufacture of the steel is proper control of heating and cooling at the rolling mill. It is not only necessary that the ingots and billets be properly heated for rolling but it is equally and in some respects more important that the cooling from the hot bed be controlled.

B. F. SHEPHERD: Mr. Davis deserves a great deal of commendation in presenting this paper and he has called attention to several facts which are also capable of much wider application than gears. One of those is lubrication, and in one of his photomicrographs he showed a gear tooth which he claimed was starting to fail due to over-stress, and the outside of that photomicrograph showed a white border. Of course, it is rather foolish to attempt to say what that metallographic constituent is from an examination of the slide, but I would like to ask Mr. Davis whether it is ferrite or not. We have had cases where severe trouble due to wear on tool steel was not due to lack of hardness of the tool steel but was due to such severe service; heavy surface pressure, combined with a small amount of very rapid movement on the surface, developed a surface temperature sufficient to thoroughly draw—and by "draw," I mean reduce the hardness to a hardness comparable to the material in its annealed state—form a very slight film on the surface, a distance of possibly 0.010 and a maximum of 0.015. Now, that soft material, of course, wore very rapidly, and as it was removed, the friction continually softened

the material underneath until the part rapidly wore out.

Mr. Davis also speaks of the heats of steel which, although of the same chemical composition, would show great differences in physical properties. I think that that is something which is going to deserve a great deal more study for the development of methods of determining these off heats of steel before they get into the regular product. In some measure it goes back to the old controversy as to whether steel, particularly tool steel, should be bought on brand name or chemical analysis, and I think that we are gradually awakening to the fact that chemical analysis in itself is only a very small part of the story.

Author's Replies to Discussion

Reply to B. F. Shepherd. The photograph to which Mr. Shepherd refers is not etched and only of 10 diameter magnification. The light areas are the high points on the tooth surfaces and the dark areas the pits. The purpose of this cut is to show the process of flaking and disintegration resulting from overstrained tooth surfaces.

I do not believe that gradual breaking down of the hard microconstituents by annealing action is initially a factor in tool failure when the edges are sharp and lubricated with oil and cutting compounds, but might be true after the edge is dulled and considerable resultant frictional heat develops. When frictional heat develops more rapidly than it is possible for the heat to be radiated by the steel mass behind the cutting edge and the heat absorption of the cutting compound, enough local temperature may be developed to soften the area of the tools affected by the cutting action.

Reply to S. A. Richardson. Mr. Richardson's data on S.A.E. 2315 and S.A.E. 2512 are, no doubt, true according to the way his tests were made, but is not exactly the same condition when we consider the forging and carburizing variables which enter into productive heat treatments.

I append a series of impact tests made on a second speed sliding gear of S.A.E. 2320, showing the results obtained from gears given both the single and double heat treatments. This test was performed by dropping a 20-pound weight onto a rack meshed with the gears tested. The gear itself was anchored in a block. In this model a 60-foot impact would have given ample factor of safety and a single heat treatment proved satisfactory. It may be noted that some of the single heat treatment gears are higher in impact than some of the double heat treatment gears, although the average is higher in the double heat treatment gears. Results are given in foot-pounds.

Single Treatment
70, 65, 80, 65, 80, 75, 65, 70, 75, 85, 70

Double Treatment
70, 95, 85, 70, 90, 75, 95, 100, 95, 95, 80

Reply to E. W. Pierce. Mr. Pierce has called attention to the variety of structures desired by different gear makers. For gear hobbing a spheroidized cementite might be best suited, whereas, for Fellow-generating a lamellar pearlite is preferred, or one with a certain percentage of sorbitic pearlite.

It is difficult to obtain any structure ideal for all tooling operations. The broaching of holes requires a sorbitic structure to obtain the best finish. S.A.E. 6150 steel would require a different structure than an S.A.E. 2350 steel and an S.A.E. 2320 different than either.

Mr. Pierce's comment on grain size in the initial steel is an important item which deserved some consideration in my paper. When one is dealing in decimals of a thousandth part of an inch and the success of gear hardening depends on so many minor factors the matter of uniformity of grain size is not to be neglected.

In regard to Mr. Pierce's comment on compactness in annealing we have not found this so important when annealing is done in an under-fired furnace. In an over-fired furnace the blast must penetrate thoroughly throughout the mass and means must be used for enough spacing between the forgings so that good circulating is possible.

Reply to M. J. MacKenzie. The impurities in steel may be classed as those rejected in the grain boundaries and those existing as mechanical impurities. Both are serious causes of gear troubles of all kinds. I have no exact data on the harmful effects of the first because our gear steel is singularly free from it. The latter, which consists of particles of slag and oxides, interferes with the accuracy of tooth cutting by peeling cutters and producing high plus streaks on the gears.

I agree with Mr. MacKenzie that all high carbon gear steel should be hot sheared. Almost any temperature above 750 degrees Fahr. is satisfactory. Even low temperatures up to 400 degrees Fahr. are better than cold shearing.

In regard to more information concerning physical vagaries we may best illustrate this by assuming that all heats of gear steel purchased within narrow chemical limits and by the best alloy practice should be always the same in the response to annealing, hardening and volumetric changes. Yet, they do not always follow obediently to established metallurgical procedure and sometimes produce baffling problems which the test tube or the microscope does not reveal. Often the same analysis of gear steel from two different makers show a marked change in properties. These differences mentioned are usually not serious but enough to necessitate some changes in heat treating practice. We may establish a volume increase standard of 0.001 inch per linear inch of volume. But it is not always 0.001 but sometimes less and sometimes more. Main drive shaft gears will sometimes warp more than at other times. The structure and Brinell hardness of annealed gears show unaccountable changes when annealed by a standardized cycle.

Mr. MacKenzie desires more information regarding forging temperatures and the prevention of decarburizing. We have found that the higher temperatures up to 2350 degrees Fahr. do not decarburize the surface in spite of the large amount of scaling or surface oxidation, but the dangerous decarburizing temperatures are between 1500 and 1800 degrees Fahr. and this is more marked in a neutral or reducing atmosphere than in an oxidizing. I favor fast forging heats and freely scaling ones to slower or soaking heats for the higher carbon gear steels.

EFFECT OF QUENCHING AND TEMPERING ON THE HARDNESS AND IMPACT RESISTANCE OF A HIGH CHROMIUM-SILICON STEEL

By F. T. Sisco

Abstract

This paper gives the result of an investigation on quenching and tempering temperatures on an alloy steel containing 1.2 per cent carbon, 1.2 per cent silicon and 18.0 per cent chromium. The best quenching temperature was found to be 1800 to 1850 degrees Fahr. The steel retains its hardness at all temperatures below 1000 degrees Fahr. The Izod impact values are low and are but little affected by varying the tempering temperatures.

FROM time to time, as new heat and oxidation resisting steels are made, samples of these steels are submitted to Wright Field to determine their possible suitability for airplane engine valves. Among the requirements of a steel for airplane valves, two points are very important: (1) the steel should not oxidize excessively at any temperature below a red heat; (2) the steel should retain its hardness at elevated temperatures. In addition a fairly tough steel, as measured by its resistance to impact, is also desirable.

The steel used in these experiments was a new high carbon, high silicon, high chromium steel with fairly good oxidation resisting properties. The composition is as follows:

	Per Cent
Carbon	1.18
Manganese	0.47
Silicon	1.20
Sulphur	0.017
Phosphorus	0.037
Chromium	18.00
Nickel	Trace

The experiments summarized in this paper were made on this steel to determine: (1) the quenching temperature which would

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The author, F. T. Sisco, is Chief, Metallurgical Laboratory, Air Corps, War Department, Wright Field, Dayton, Ohio. Manuscript received July 31, 1928.

give the best combination of hardness and toughness, and (2) the effect of the tempering temperature on these two properties.

The material available was in the form of a hot-rolled and annealed 1⅛ inch round bar. One hundred and eight standard Izod V-notch impact[1] specimens were machined from this bar. Forty-five of these specimens were used to determine the effect of quenching temperature and 63 specimens were used to determine the effect of tempering temperatures. The various quenching and tempering temperatures are shown in Tables I, II and III. All quenching was in oil.

Brinell hardness (3000 kilograms, 10-millimeter ball) and Rockwell hardness (150-kilogram load, C Scale) tests were made on

Table I

Effect of Quenching Temperature on Impact Resistance and Hardness of High Chromium Silicon Steel Tempered at 800 Degrees Fahr. Izod V-notch Impact—Average of Two Tests

Quenching Temperature degrees Fahr.	Izod Impact ft. lb.	Rockwell Hardness C scale—150 kg.
1450	1.25	18.2
1500	1.25	18.0
1550	2.00	18.7
1600	2.50	42.7
1650	2.50	46.0
1700	2.00	51.3
1750	3.00	53.2
1800	3.00	55.5
1850	3.00	57.0
1900	3.00	57.9
1950	3.50	57.0
2000	3.50	55.7
2050	4.00	51.3
2100	5.00	42.7
2150	4.50	39.9

the impact specimens after these were broken. Metallographic specimens were taken from the end of the impact specimen.

Impact results are given in actual foot pounds. The specimens were machined with sufficient accuracy so that it was not necessary to reduce the impact value to foot pounds per square inch.

Results

The effect of varying the quenching temperature for a temper-

[1]The standard Izod V-notch specimen used was: 2.950 inches x 0.394 inch x 0.394 inch with a 45-degree notch 0.079 inch deep.

Table II

Effect of Quenching Temperature on Impact Resistance and Hardness of High Chromium Silicon Steel Tempered at 1100 Degrees Fahr.

Izod V-notch

Quenching Temperature degrees Fahr.	Izod Impact ft. lb.	Rockwell Hardness C scale—150 kg.
1450	Not tested	...
1500	Not tested	...
1550	2.00	19.5
1600	2.00	33.8
1650	2.00	36.3
1700	3.00	38.8
1750	4.00	40.3
1800	3.50	41.3
1850	3.50	42.3
1900	3.00	44.0
1950	3.50	44.5
2000	3.50	46.3
2050	2.00	53.3
2100	2.50	54.3
2150	4.00	44.3

ing temperature of 800 degrees Fahr. is shown in Table I, and for a tempering temperature of 1100 degrees Fahr. in Table II.

The steel starts to harden when quenched from 1600 degrees Fahr. and attains its maximum hardness with hardening temperatures between 1800 to 1950 degrees Fahr. When quenched from 2000 degrees Fahr. and above, an increasing amount of austenite is formed with corresponding decrease in hardness (Table I). An interesting fact brought out by the impact results is the low resistance of the steel quenched from 1450 to 1550 degrees Fahr.; temperatures apparently below the hardening range. The impact resistance remains fairly constant for quenching temperatures of 1750 to 2000 degrees Fahr. Above 2000 degrees Fahr. (Table I) the impact value increases with the retention of an appreciable amount of austenite.

Table II also shows that the steel attains its maximum hardness when quenched from 1850 to 2000 degrees Fahr. The higher tempering temperature, 1100 degrees Fahr., has had the effect of transforming the austenite formed, either wholly or partially, with quenching temperatures of 2000 degrees Fahr. and above, to martensite. This is apparent from the hardness results in Table II.

From the results obtained by varying the quenching temperature (Tables I and II) a temperature of 1800 to 1850 degrees Fahr.

Table III

Effect of Tempering Temperature on Impact Resistance and Hardness of High Chromium Silicon Steel Quenched in Oil from 1800 Degrees Fahr. Average of Three Tests

Drawing Temperature degrees Fahr.	Izod Impact ft. lb.	Rockwell C Scale	Brinell
As Received Annealed	2.41	19.0	231
None	2.75	59.0	608
400	3.25	56.0	560
500	2.60	55.8	555
600	3.01	55.5	547
700	2.83	56.0	560
800	2.58	56.0	560
900	2.75	58.0	573
950	2.91	57.3	575
1000	3.00	54.7	534
1050	2.75	47.0	441
1100	2.91	42.5	401
1150	3.41	41.0	380
1200	4.00	40.0	373
1250	3.80	38.0	352
1300	4.25	35.0	333
1350	4.30	33.0	313
1400	5.10	29.7	290
1450	4.31	28.5	280
1500	4.33	26.0	263
1550	4.33	25.0	259

was fixed for the tempering experiments. These results are given in Table III. Two important facts are brought out in this table: (1) the hardness of this steel quenched in oil from 1800 degrees Fahr. does not diminish until a tempering temperature of 1000 degrees Fahr. is reached; (2) the impact resistance remains fairly constant for tempering temperatures of 1100 degrees Fahr. and below. At this temperature it increases slightly but remains practically constant for all tempering temperatures above 1100 degrees Fahr.

The difference in impact resistance for the steel quenched and tempered at 1500 to 1550 degrees Fahr. and the same steel in the annealed condition should be noted. As received the material had an impact resistance of 2.4 foot pounds and a Brinell hardness of 231 (Table III). As quenched in oil from 1800 degrees Fahr. and tempered at 1500 to 1550 degrees Fahr. the impact resistance was 4.3 foot pounds and the Brinell hardness 260 (Table III).

The microscopic structure of the steel after various treatments shows little of importance. Fig. 1, is the average structure of the

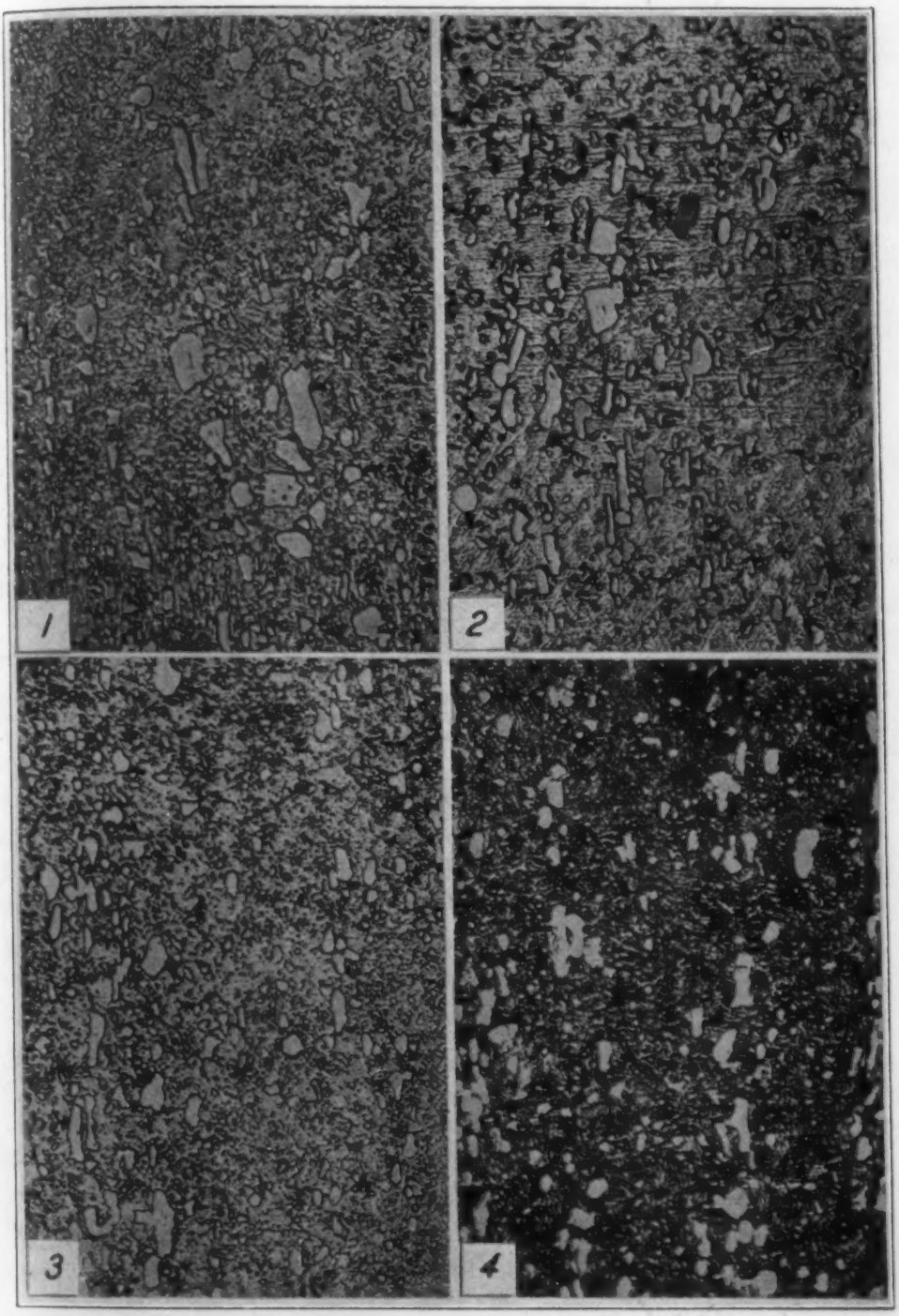

Fig. 1—Photomicrograph Showing Average Structure of the Longitudinal Section of the Material as Received. Fig. 2—Photomicrograph Showing the Structure of the Material as Quenched in Oil from 1800 Degrees Fahr., but not Tempered. Fig. 3—Photomicrograph of Material Showing the Structure as Quenched and Tempered at 950 Degrees Fahr. Fig. 4—Photomicrograph Showing the Structure of the Material as Quenched and Tempered at 1200 Degrees Fahr. Magnification Figs. 1, 2, 3, 4, × 500.

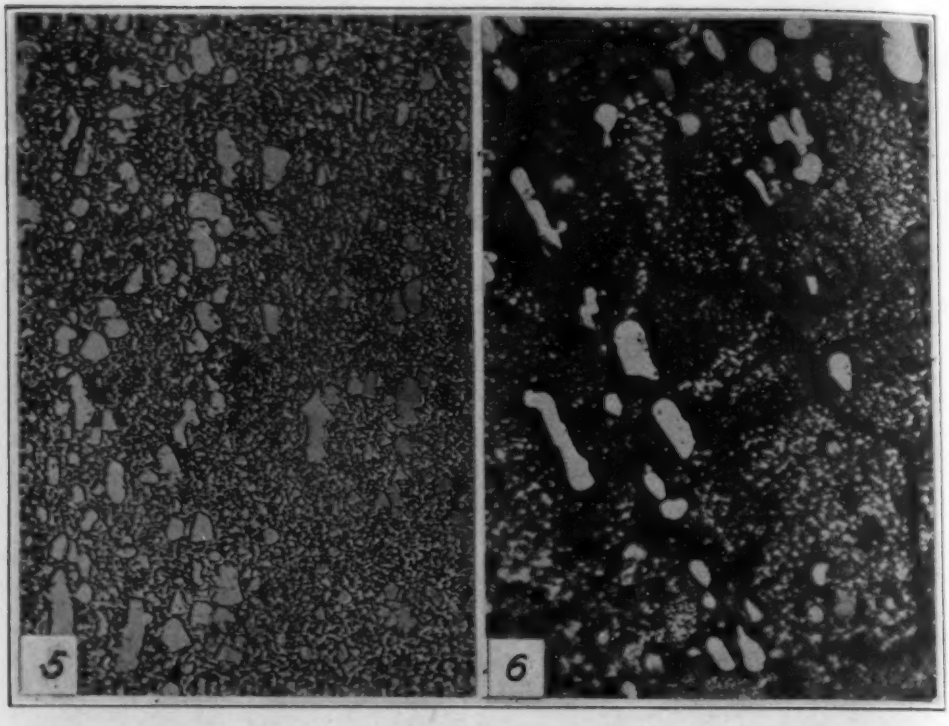

Fig. 5—Photomicrograph Showing Structure of the Material as Quenched and Tempered at 1500 Degrees Fahr. Fig. 6—Photomicrograph Showing Structure of Specimen Quenched in Oil from 2100 Degrees Fahr. and not Tempered. Magnification Fig. 5, × 500; Fig. 6, × 1000.

longitudinal section of the material as received, and Fig. 2, as quenched in oil from 1800 degrees Fahr. but not tempered. There is no indication of austenite in the microstructure of the hardened specimen. Fig. 3, is quenched and tempered at 950 degrees Fahr. The structure is very similar to that shown in Fig. 2. Tempering at 1200 degrees Fahr. has mostly transformed the martensitic matrix evident in Figs. 2 and 3, probably to troosto-sorbite (Fig. 4). The highest tempering temperature, 1500 degrees Fahr. has changed the structure further (Fig. 5) until it resembles closely the structure of the annealed material (compare Fig. 5 and Fig. 1).

The retention of austenite when this steel is quenched from 2100 degrees Fahr., as indicated by the lowered hardness in Tables I and II, is evident in Fig. 6. This specimen quenched in oil from 2100 degrees Fahr. and not tempered shows the characteristic austenite grains.

In preparing the steel for microscopic examination it was found to be impossible to etch the specimens in alcoholic nitric or alcoholic picric acid. These two common etchants had no effect

on the polished surface. Consequently a nitric acid solution of ferric chloride had to be used.

Conclusions

1. Steel containing 1.2 per cent carbon, 1.2 per cent silicon, and 18.0 per cent chromium attains the maximum hardness when quenched in oil from 1850 degrees Fahr.

2. Steel of this composition retains its hardness for all tempering temperatures below 1000 degrees Fahr.

3. The steel has low resistance to impact. The resistance is but slightly affected by high tempering temperatures.

4. Quenching below 1600 degrees Fahr. does not harden the material. Quenching above 2000 degrees Fahr. results in the formation of some austenite with lowered hardness and increased notch toughness.

SILICON-MANGANESE STEELS WITH CHROMIUM ADDITIONS FOR ENGINEERING APPLICATIONS

By A. B. Kinzel

Abstract

This paper discusses silicon-manganese steels of medium carbon content. It states that these steels are highly suitable for engineering purposes and are susceptible to heat treatment. The addition of a hardening element, particularly one per cent chromium, increases the susceptibility to heat treatment and ease of application of heat treatment. Silicon-manganese-chromium steels are stated to be superior to silicon-manganese or straight manganese steels similarly heat treated. Physical properties of the silicon-manganese-chromium steels are said to be of the same order as those of the best alloy steels similarly heat treated.

Introduction

THE use of silicon steel and silicon-manganese steel for structural purposes has long been known and the status of these steels has been well described by Dr. H. W. Gillett in the Bureau of Standards Technologic Paper No. 331. In this paper Dr. Gillett reviews the history, gives the properties and status of these steels and includes a very excellent bibliography. In addition to the facts brought out by Dr. Gillett it is generally known that a silicon-manganese steel with a high carbon content is well adapted to certain tools and that a silicon-manganese steel with a medium carbon content is suitable for springs. The value of heat treated silicon-manganese steels for automotive parts and general engineering purposes of a similar nature has not been generally appreciated, although the use of manganese steels for these purposes is fairly general.

Accordingly, a study of the effect of heat treatment on steels with varying silicon and manganese contents in the 0.20 to 0.40

A paper presented before the tenth annual convention of the American Society for Steel Treating, held in Philadelphia, October 8 to 12, 1928. The author, A. B. Kinzel, a member of the society, is metallurgist with the Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y. Manuscript received August 7, 1928.

per cent carbon range has been made. This has been followed by the study of the effects of hardening elements, particularly chromium, in order to make the heat treatments more effective.

Silicon-Manganese Steels

In the study of these steels a few preliminary heats were made in a laboratory 6-pound induction furnace to indicate the carbon range desired. This was not deemed to be a satisfactory method for general study as the size of the heats was too small to be representative of results obtainable in commercial practice. Accordingly, 300-pound heats of the material were made in an electric furnace and in each case the heat was split in three ladles with varying silicon additions. Table I shows the analyses of these heats.

Table I
Chemical Composition of Steels

Heat	Per Cent C	Mn	P	S	Si
1 — A	0.24	0.59	0.019	0.004	0.39
1 — C					0.54
1 — B					0.85
2 — A	0.29	0.97	0.017	0.002	0.50
2 — B					0.71
2 — C					0.99
3 — A	0.37	1.04	0.013	0.002	0.78
3 — B					1.01
3 — C					1.32
3 — D					1.60
4 — A	0.38	1.58	0.017	0.002	0.56
4 — B					0.60
4 — C					0.82

Heat No. 1 contained a small amount of vanadium and heat No. 3 small amounts of chromium and vanadium picked up from the scrap or furnace lining. The quantities were considered to be too small to affect the results.

It is appreciated that the sulphur and phosphorus are very low and that the properties are probably somewhat improved. However, the material was cast in small ingots so that the reduction in area on hot working was much less than in the case of usual commercial practice, and the properties were probably somewhat adversely affected. It is realized that these steels may not be directly compared to the usual large scale commercial alloy steels, although the general category into which they fall may be fairly well esti-

Table II
Physical Properties of Heat No. 2 Following Various Treatments

		Quench	Temper	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds
A	As forged and rolled			58	92	26	50	28f
B				59	93	28	54	36f
C				61	95	25	48	33f
A	Annealed			51	86	27	49	..
B				52	85	26	42	39f
C				60	88	28	53	..
A		1650° F. Air	....	57	92	29	62	32f
B				59	94	28	62	32f
C				67	94	30	62	40f
A		1740° F. Air	....	60	93	28	61	35f
B				58	94	28	61	32f
C				63	94	30	60	26f
A		1610° F. Oil	980° F.	100	114	11	52	57d
B				118	137	14	51	53d
C				92	117	19	56	63d
A		1650° F. Oil	890° F.	85	116	18	52	58d
B				83	116	17	53	50f
C				89	115	20	54	59d
A		1740° F. Oil	890° F.	77	109	18	55	30f
B				82	121	20	46	40f
C				85	117	19	49	45f
A		1650° F. Water	980° F.	116	130	19	59	62d
B				116	132	18	58	64d
C				122	135	20	58	72d
A		1650° F. Water	890° F.	139	150	10	38	50f
B				137	152	13	47	48f
C				141	155	11	42	53f
A		1650° F. Water	800° F.	147	164	9	40	46f
B				147	164	13	46	42f
C				153	169	13	48	42f

d—deformation or bend
f—fracture or break
Composition of Heat No. 2—C 0.30 per cent, Mn 1.00 per cent, Si 0.50, 0.71, 0.99 per cent.

mated. Accordingly the tables give values for comparative purposes on steels made in the same way except when otherwise specifically stated.

The material forged and rolled with great ease. Heat No. 2 was chosen to make a detailed study of the effect of heat treatment. The results of this study are shown in Table II.

It will be seen that the steels as forged and rolled have physical properties which compare favorably with those obtained after an-

Table III

Physical Properties of Silicon-Manganese Steels after Water Quenching from 1650 Degrees Fahr. and Tempering at 890 Degrees Fahr.

	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds	Per Cent Mn	Per Cent Si	Per Cent C
1 — A	122	132	11	56	67d	0.59	0.37	0.24
C	120	133	8	46P	42d		0.54	
B	130	146	13	52	52d		0.85	
2 — A	139	150	10	38	50f	0.97	0.52	0.29
B	137	152	13	47	48f		0.71	
C	141	155	11	42	53f		0.88	
3 — A	146	159	12	40	41f	1.04	0.78	0.37
B	146	160	14	47	46d		1.01	
C	148	161	15	50	44f		1.32	
D	130	160	12	40	30f		1.60	
D (750° F. Temper)	190	210	10	41	23f P		1.60	
4 — A	147	159	13	54	49f	1.58	0.55	0.38
B	143	156	14	48P	48d		0.60	
C	148	158	15	47	44f		0.84	

d—deformation or bend
f—fracture or break

nealing or normalizing. As would be expected that quenching in oil and tempering gives properties decidedly better than normalizing; not only is the strength increased but the ductility is improved as well. Within the limits used, the quenching temperature has not affected the results appreciably, although 1650 degrees Fahr. (900 degrees Cent.) seems to be the optimum temperature. Water quenching with subsequent tempering still further improves the properties. The superiority of the values after water quenching over the values after oil quenching is striking.. This is undoubtedly due to the more effective quenching of the low carbon steel. The effect of tempering temperatures will be noted to be typical; an increase in the temperature of tempering decreasing the tensile properties and improving the ductility.

Based on the results obtained with this heat, the other heats of this series were water-quenched from 1650 degrees Fahr. (900 degrees Cent.) and tempered at 890 degrees Fahr. (475 degrees Cent.) Specimens were air-cooled from the tempering operation, it having been determined that the properties were not affected by air cooling or furnace cooling from the tempering temperatures. In addition,

another set of samples was simply normalized from 1650 degrees Fahr. (900 degrees Cent.) Table III shows the results obtained.

It will be noted that the effect of silicon is to increase the physical values with increasing silicon content, although above 1 per cent silicon the improvement seems to be relatively small and a decrease in value of properties is noted with the very high silicon

Table IV

Physical Properties of Silicon-Manganese Steels after Normalizing

	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds	Per Cent Mn	Per Cent Si	Per Cent C
1 — A	58	77	26	57	58d	0.59	0.37	0.24
C	55	79	32	61	53d		0.54	
B	61	85	30	63	58d		0.85	
2 — A	57	92	29	62	32f	0.97	0.52	0.28
B	59	94	28	62	32f		0.71	
C	67	94	30	62	40f		0.88	
3 — A	67	97	20	47		1.04	0.78	0.37
B	73	104	27	60	30f		1.01	
C	76	106	27	58	25f		1.32	
D	80	111	25	50	28f		1.60	
4 — A	73	109	20	54	23f	1.58	0.55	0.38
B	71	109	22	54	24f		0.60	
C	76	109	21	50	26f		0.84	

d—deformation or bend
f—fracture or break

(3-D). The properties of this specimen were checked after a 1740-degree Fahr. (950-degree Cent.) quench. The effect of manganese in the heat treated state is also to increase the physical properties with increasing manganese, although here again the increase with more than 1 per cent manganese seems to be small. Carbon does not seem to have a very marked effect in the narrow range used, although it seems that 0.35 per cent carbon is better than 0.25 per cent. From the above data it would seem that 1 per cent manganese, 1 per cent silicon, and 0.30 to 0.35 per cent carbon is the best analysis for this type of steel.

The properties on normalizing are of course very different. Normalizing fails to bring out the full effect of the alloying elements and although the results are still very good, they do not have

Table V

Physical Properties of Several Alloy Steels Air-Cooled from 1650 Degrees Fahr.

V	C	Cr	Si	Mn	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds	Brinell
	0.34	0.38	0.91	1.04	72	111	25	60	26	207
	0.34	0.73	0.91	1.04	75	122	20	58	12	241
	0.34	0.95	0.91	1.04	79	126	21	59	13	302
0.18	0.34	0.94	0.91	0.72	93	131	19	59	6	
	0.28		0.90	0.97	67	94	30	62	40	
	0.41			1.25*	61	117	17	45	18	

*Air-cooled from 1500 degrees Fahr.

the striking excellence of the heat treated steels. Table IV shows the values obtained.

It should be noted that a higher carbon content raises the ultimate strength, but at the sacrifice of ductility. Increasing the silicon content increases the tensile strength, but not markedly. The effect of manganese, particularly up to 1 per cent, is much more important and decidedly beneficial. Thus, from the data for normalizing, the most suitable analysis would be 1 per cent manganese, 1 per cent silicon and 0.30 per cent carbon.

The following list of values is chosen from the table to illustrate what may be expected from the heat treated 1 per cent silicon, 1 per cent manganese and 0.35 per cent carbon steels.

Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds
122	135	20	58	72d
148	161	15	50	44f
153	169	13	48	42f
190	210	10	41	23f

It is appreciated that in a great many cases water quenching is impractical and that for certain applications the mass of the material might be such as to make even a water quench uneffective.

In view of the excellent results obtained, particularly in the water-quenched and tempered state, and in view of the fact that the oil-quenched and tempered material shows properties which are not nearly as good as the water-quenched, the author visualized an improvement in these steels by the addition of a suitable hardening element. The addition of such an alloying element would so modify

Table VI
Physical Properties of Several Alloy Steels Oil-Quenched from 1650 Degrees Fahr. and Tempered at 930 Degrees Fahr.

V	C	Cr	Si	Mn	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds	Brinell
	0.34	0.38	0.91	1.04	136	151	18	50	35	321
	0.34	0.73	0.91	1.04	150	166	15	50	24	340
	0.34	0.95	0.91	1.04	151	167	15	48	24	340
0.18	0.34	0.94	0.91	0.76*	158	175	12	39	24	

*Tempered at 975 degrees Fahr.

the characteristics of the steel as to make the effect of an oil quench on the modified steel more nearly like that of a water quench on the original steel and would increase the quenching effect of air cooling. Chromium is one element with which to accomplish this, although molybdenum, tungsten, vanadium and the like have also been used.

Accordingly, 6-pound heats were made with varying chromium, silicon, manganese and carbon contents. The results obtained on the 6-pound heats showed the most suitable range but were not considered as sufficiently representative. Accordingly, a 300-pound heat split into three parts—carbon, 0.34 per cent; silicon, 0.91 per cent; manganese, 1.04 per cent; and chromium, 0.38, 0.73 and 0.95 per cent, respectively, was made. The ingots were forged and rolled in the laboratory, no difficulty whatever being experienced in the reduction. Tensile test specimens and impact specimens were air-cooled from 1650 degrees Fahr. (900 degrees Cent.) and others were oil-quenched from 1650 degrees Fahr. (900 degrees Cent.) and tempered at 930 degrees Fahr. (500 degrees Cent.) and 800 degrees Fahr. (425 degrees Cent.) respectively. Table V shows the results of air cooling, together with some results previously obtained on other steels made in the same way, the analysis of which is given. Tables VI and VII give values obtained on heat treatment.

It will be noted that the tensile properties increase with the chromium content and that the tensile test ductility does not appreciably drop off, although the shock resistance does. Aside from the shock resistance, the steels are well superior to silicon-man-

Table VII

Physical Properties of Several Alloy Steels Oil-Quenched from 1650 Degrees Fahr. and Tempered as Shown

V	Cr	Si	Mn	Tempering Treatment	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent	Izod foot-pounds	Brinell
0.34	0.38	0.91	1.04	800° F.	140	159			23	340
0.34	0.73	0.91	1.04	800° F.	177	201	10	42	26	375
0.34	0.95	0.91	1.04	800° F.	178	201	10	38	22	387
0.28		0.90	0.97	890° F.	89	115	20	54	59d	
0.41			1.52*		127	141	10	50	25	
0.28		0.90	0.97**		153	169	13	48	42	

d—deformation or bend.
*Oil-Quenched from 1560 degrees Fahr. Tempered 750 degrees Fahr.
**Water-Quenched from 1650 degrees Fahr. Tempered at 800 degrees Fahr.

ganese steels and manganese steels in the normalized state. When the impact value is taken into consideration, it is a question of weighing the results, depending on the particular application in mind.

In the oil-quenched and tempered condition the superiority of the silicon-manganese chromium steels is even more pronounced. The values are only equalled by the water-quenched silicon-manganese steel while those of the manganese steels fall short of them.

In the writer's opinion, judging from the data at hand, the general physical properties of these steels compare very favorably

Table VIII

	Per Cent									
	C	Si	Mn	Cr	V	Ni	Yield Point, M. lbs. per sq. in.	Ultimate Strength, M. lbs. per sq. in.	Elongation per cent in 2 in.	Reduction of Area, per cent
S.A.E.	0.34	0.91	1.04	0.38			136	151	18	50
	0.34	0.91	1.04	0.73			178	201	10	42
	0.34	0.91	1.04	0.95			151	167	15	48
2330	0.30					3.5	128	152	12	52
3130	0.30			0.60		1.25	125	150	15	57
3230	0.30			1.10		1.75	152	178	15	48
3435	0.35			0.80		3.00	162	188	14	55
6145	0.45			0.95	0.18		142	167	20	53
6130*	0.30			1.00	0.18		180	200	14	50

*Water quenched.

with those of the other steels here mentioned. For purposes of further comparison Table VIII includes some published values on various alloy steels of the S.A.E. series, all oil-quenched and tempered except 6130, which has been water-quenched. It is obvious that no absolute comparison may be made due to the different conditions of manufacture of the silicon-manganese-chromium steels and the S.A.E. steels. However, it is evident that the physical properties of the silicon-manganese-chromium steels are of the same general order as those of the more expensive S.A.E. steels here shown. Figures which are completely satisfactory for purposes of comparison must await the production of the former steels on a manufacturing scale.

Silicon-Manganese Steels with Chromium and Tungsten Additions

In order to indicate the nature of the change which is produced by the addition of another hardening element the results of a heat which was made in the 6-pound furnace with the following analysis are given:

	Per Cent
Carbon	0.24
Chromium	0.96
Manganese	1.06
Tungsten	2.33
Silicon	1.25

The material forged and rolled with ease. On normalizing from 1650 degrees Fahr. (900 degrees Cent.) and tempering at 750 degrees Fahr. (400 degrees Cent.) this gave a yield point of 115,000 pounds per square inch, an ultimate strength of 147,000 pounds per square inch, 20 per cent elongation and 45 per cent reduction of area with an Izod value of 30f. This shows that material of this analysis when normalized and tempered has characteristics similar to the straight silicon-manganese steels as quenched and tempered. When water-quenched and tempered at 890 degrees Fahr. (475 degrees Cent.) a yield point of 170,000 pounds per square inch and 194,000 pounds per square inch ultimate strength resulted. The ductility, however, was very poor. Three per cent elongation, 16 per cent reduction of area and 14 foot pounds Izod resulted. This probably could be improved by

the use of a suitable tempering temperature. The results illustrate the fact that the addition of hardening elements other than chromium either alone or in combination with chromium allow a much less drastic quench to be used to obtain a satisfactory quenching effect.

Conclusions

1. Silicon-manganese steels of medium carbon content (0.35 per cent) are highly suitable for engineering purposes and decidedly susceptible to heat treatment.
2. The susceptibility to heat treatment and ease of application of heat treatment of the above steels is greatly improved by the addition of a hardening element, notably 1 per cent chromium.
3. The physical properties of the silicon-manganese-chromium steels are superior to those of the silicon-manganese or straight manganese steels similarly heat treated.
4. The physical properties of the silicon-manganese-chromium steels here shown are of the same order as those of the best alloy steels similarly heat treated.

Acknowledgment

The writer wishes to express his appreciation of the interest and stimulation given by Messrs. F. M. Becket, president, and J. H. Critchett, vice-president of the Union Carbide and Carbon Research Laboratories, Inc., and of the assistance rendered by J. J. Egan in carrying out the work.

DISCUSSION

Alvan L. Davis: Mr. Kinzel's paper interests me very much, not so much on account of its novelty, as on account of its being brought forward before this society. The type of steel which he speaks of is a steel which has been made, I believe, by many steel companies. The Crucible Steel Company of America as far back as 15 years ago made it commercially. It probably has not won the place that it deserves in the annals of this society and, perhaps, of the automotive societies. I think it is true, though, that the silicon-manganese steels form a proper base which can be toned up and improved by the addition of not only chromium, but also nickel, and if it comes to a question of producing the very best thing that you can get, where you must have the maximum ductility for a given strength, then you may go to the extent of adding vanadium as well. A case where that would come in, as well as in aircraft engineering, is in gun shields, where we require the maximum protection for the smallest

weight. During the world war a great many gun shields were turned out of this type, a silicon-manganese base, hardened with chromium and vanadium and, in some cases, with nickel, too.

So it is not so much as an innovation that Mr. Kinzel's paper comes before us, but by way of getting this information before people who ought to have it. For that reason I think it is very apropos.

I might add that I had in mind steels containing about two per cent silicon.

Author's Reply to Discussion

It is true, as I said in my opening remarks, that silicon-manganese steel is not a new steel. It is also true that silicon-manganse steel has not won the place in the field of heat treated steel that it should have. I think that one reason for this is that most of the silicon-manganese steel used has been of comparatively low silicon or manganese type. To the best of the writer's knowledge this steel has a much higher silicon and manganese content than has been used in the previous steels to which other alloys have been added.

With respect to the alloy steels for ordnance purposes mentioned by Mr. Davis, as far as the writer can find out this work was all done on a nickel-silicon steel base and not a manganese-silicon steel base. Since giving the discussion, Mr. Davis has referred the writer to an article by Mr. Johnson in the American Society for Steel Treating, TRANSACTIONS, March, 1922. It will be noted that here again the base is nickel-silicon and no mention of the manganese-silicon is made. In view of these facts, the writer feels he is correct in his original assertion that the steels here discussed are novel. However, he is very appreciative of Mr. Davis' discussion and realizes that he and Mr. Davis are in complete accord as to the technical and economical value of these steels.

A NEW DEVELOPMENT IN CORROSION-RESISTING STEEL

By F. R. Palmer

Abstract

This paper points out a satisfactory means for improving the machinability and grinding properties of high-chromium, corrosion-resisting steels.

The effect of phosphorus and sulphur on these steels is briefly discussed and the use of zirconium sulphide is considered in detail.

A free-machining corrosion-resisting steel is described and its properties enumerated.

THE machinability of high-chromium, corrosion-resisting steels has been the subject of much study in shops where its use has been considered. Certain machining operations have been economically handled by specially ground or specially designed tools, but there is an urgent need for a free cutting "stainless" steel which can be cut rapidly and economically with the ordinary shop tools and equipment. It was toward the solution of this problem that the present study was directed.

The difficulty in machining high-chromium steels does not lie in their inherent hardness nor is it because they work-harden like manganese steel, their case is rather unique. The difficulty lies in the manner in which the chips adhere to the cutting edge of the tool. For some reason these steels have a very high coefficient of friction and tend to adhere to any surface with which they are brought into dynamic contact. This same tendency causes difficulty in grinding due to the chips adhering to the grits and thus loading the wheel.

Of collateral interest is the tendency of these high-chromium, corrosion-resisting steels to gall, scratch, or seize in service. Pump shafts, valve stems, gate valve seats and similar moving parts sometimes gall or seize—particularly if the pressures are high, and it was expected that a solution to the machining problem would favorably affect these other factors.

A paper presented before the tenth annual convention of the society held in Philadelphia, October 8 to 12, 1928. The author, F. R. Palmer, a member of the society, is assistant to the president of the Carpenter Steel Company, Reading, Pa. Manuscript received July 19, 1928.

Development

The original research on this problem centered about a corrosion-resisting steel, (frequently called "stainless iron"), of the following type analysis:

Carbon	Manganese	Silicon	Chromium
0.10 per cent	0.40 per cent	0.40 per cent	14.00 per cent

The work developed in three distinct stages.

First, a series of steels was melted in which there was added to the above steel, phosphorus and sulphur—individually and jointly, in quantities up to about 0.12 per cent. These analyses forged and rolled well but showed little or no improvement in machinability. There was some evidence of improvement as the sulphur approached 0.12 per cent but high phosphorus seemed to have no beneficial effect whatever.

The second stage consisted in adding abnormally large quantities of these metalloids, thus producing a series of twenty-two analyses containing phosphorus up to 0.50 per cent and sulphur up to 2.00 per cent with intermediate combinations of both elements. It is fruitless to go into detailed properties of each of these analyses since they served only as a means to an end,—and the end was not yet.

It developed that phosphorus alone had little, if any, beneficial effect on the machining properties. On the other hand, this element, even up to 0.50 per cent did not interfere seriously with the hot working properties, although the temperatures were considerately held around 1800 degrees Fahr.

Sulphur began to affect adversely the hot workability as soon as the additions exceeded about 0.15 per cent and all analyses, over about 0.20 per cent sulphur were commercially unworkable. However, where forged specimens could not be secured, machining tests were made on cast specimens and it was found that sulphur was the answer to the problem. The first beneficial effect of sulphur was noticed at about 0.12 per cent. Maximum machining properties were obtained in the neighborhood of 0.30 per cent and while analyses were investigated up to 2.00 per cent sulphur, there was no worthwhile improvement above 0.30 per cent.

Although sulphur had solved the original problem, it had in-

troduced another just as serious, namely, red shortness. Manganese, the normal antidote for high sulphur, was not available in this instance because high manganese is known to greatly reduce the corrosion resistance of the metal.

The third phase of the development consisted in finding a form of sulphur which retained all the advantages of the pure metalloid with none of its disadvantages. It ultimately developed that "zirconium sulphide" completely answered this specification. Accordingly, the ultimate analysis proved to be—

Carbon	Chromium	Zirconium Sulphide
0.10 per cent	14.00 per cent	0.40 per cent

This zirconium sulphide treatment was applied to steels with chromium contents from 7.00 per cent to over 25.00 per cent, and, in all cases, it functioned effectively.

Analysis

There is no type of high-chromium, corrosion-resisting steel which is better known nor more commonly used than that variety known as "stainless iron," containing about 0.10 per cent carbon and 12.00 to 14.00 chromium. Accordingly, this type will be selected to describe the effect of zirconium sulphide and comparisons will be drawn between the base analysis with and without zirconium sulphide additions. The type analyses of the two steels to be considered may be taken as follows:

	Steel 1 Per Cent	Steel 2 Per Cent
Carbon	0.10	0.10
Manganese	0.40	0.40
Silicon	0.40	0.40
Phosphorus	0.020	0.020
Chromium	14.00	14.00
Zirconium Sulphide	Nil	0.40

The use of "zirconium sulphide" in the analysis might logically be questioned. Why not report them separately as sulphur and zirconium? This is not done because it would be totally misleading. It has already been shown that sulphur in excess of 0.15 per cent ruins the hot working qualities of the metal. It has other objectionable features which make it impractical to use as

an alloy in corrosion-resisting steel. Zirconium sulphide, on the other hand, is a brand new component having properties of its own, and these properties are distinctly different from sulphur, (or manganese sulphide), in many ways.

Fig. 1 shows an interesting example of this difference. Here

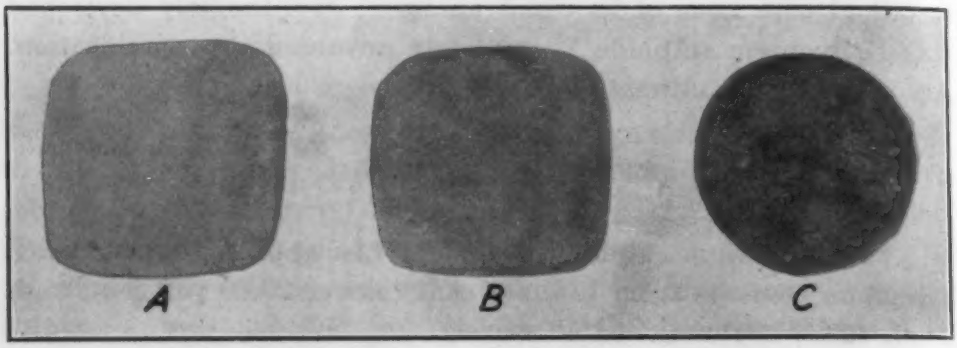

Fig. 1—Sulphur Prints Showing that Zirconium Sulphide Does not Record on a Sulphur Print. A is Steel No. 1. B is Steel No. 2. C is Common Screw Stock.

we have illustrated sulphur prints of regular stainless iron, the new free machining stainless iron treated with zirconium sulphide and Bessemer screw stock. It will be seen that there is no more sulphur printed on the new steel than on the regular stainless iron

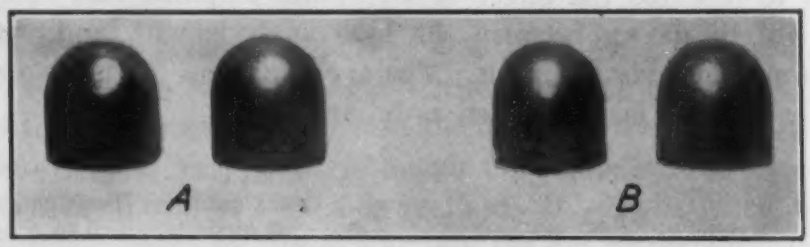

Fig. 2—Photograph of Corrosion Test Specimens Exposed to 5 Per Cent Sea Salt Spray for 240 Hours. A. Specimens of Steel No. 1 (Stainless Iron.) B. Specimens of Steel No. 2 (Stainless Iron with Zirconium Sulphide.)

proving that there is no more sulphur, (or manganese sulphide), present. This forms an interesting contrast with the screw stock which contains 0.080 per cent. This same distinction between sulphur, (manganese sulphide), and zirconium sulphide is further confirmed by the hot working properties, the corrosion-resisting properties and the physical properties, hence it is deemed advisable to report the sulphur in the analysis as zirconium sulphide.

Corrosion-Resisting Properties

Zirconium sulphide appears to affect in no way the corrosion-resisting properties of the base analysis. Fig. 2 shows typical samples after 240 hours exposure in a 5 per cent salt spray. Commercial tests further indicate that the zirconium treated product will work out satisfactorily in contact with the same chemicals as are resisted by ordinary stainless iron.

Scale Resistance

The comparative resistance to scaling at elevated tempera-

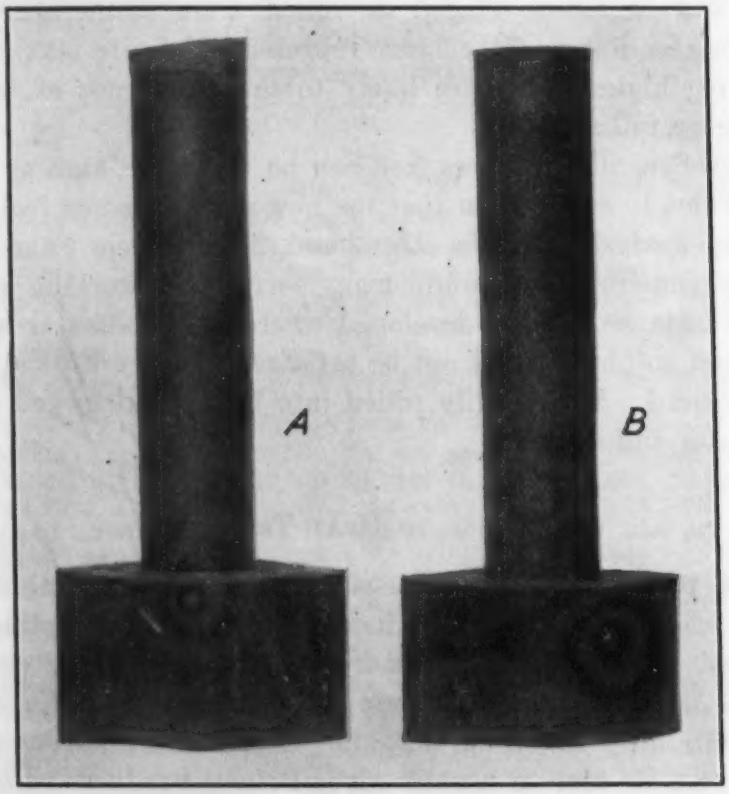

Fig. 3—Photograph of Scale Test Specimens Exposed to 1600 Degrees Fahr., for 8 Hours. Specimen A is Steel No. 1. Specimen B is Steel No. 2.

tures is illustrated in Fig. 3. The specimens were prepared by machining hot rolled bars down to about ½-inch diameter with a finely prepared surface. Both pieces were exposed at the same time to a temperature of 1600 degrees Fahr. for eight hours in an electrically heated muffle furnace. Vents were provided in the front and back of the furnace for free passage of air.

With the exception of a small patch of scale near the end of the stainless iron sample, there was no loose peeling scale acquired by either specimen. The surface is covered with a tight, dark gray film of scarcely measurable thickness. We should regard these two samples as equal in scale resistance, showing that zirconium sulphide has no effect upon this property of the steel.

Hot Working Properties

Stainless iron treated with about 0.40 per cent zirconium sulphide can be safely forged or rolled from temperatures up to 2100 degrees Fahr. This figure represents the safe maximum temperature; higher heats are likely to show evidence of tearing in forging or rolling.

Since regular stainless iron can be forged as high as 2300 degrees Fahr. it will be seen that the new steel is not as fool-proof as the older analysis. On the other hand, 2100 degrees Fahr. is a reasonable temperature to conduct any sort of hot working operation, and no instance has yet developed where the product treated with zirconium sulphide could not be satisfactorily hot worked into the form desired. It is readily rolled into bars, drop forged or rolled into plates and sheets.

Response to Heat Treatment

The presence of zirconium sulphide in high-chromium, corrosion-resisting steels seems to increase the critical cooling speed. It is well known that stainless iron of the type being considered hardens almost as readily in air as it does in oil. The modified type, containing zirconium sulphide, does not air harden quite so readily and air cooling usually gives Brinell hardness values 50 to 100 points lower than oil quenching.

Stainless iron containing zirconium sulphide will harden in oil but does not become quite as hard as the same analysis without the zirconium sulphide.

It has also been observed that zirconium sulphide raises the temperature necessary for hardening stainless iron. Whereas the base analysis will harden very satisfactorily at 1700 degrees Fahr., with the addition of 0.40 per cent zirconium sulphide, it becomes

necessary to raise the hardening temperature to about 1825 degrees Fahr.

On tempering stainless iron, the martensite break-down temperature is about 950 degrees Fahr. Zirconium sulphide does not alter this figure.

Tensile Properties

Typical tensile properties of stainless iron, both with and without zirconium sulphide, are shown in Table I.

Table I
Tensile Properties of Stainless Iron

	Steel 1 Stainless Iron	Steel 2 Stainless Iron plus Zirconium Sulphide
Hardened and Tempered at 700 Degrees Fahr.		
Yield Point	125,800 lbs. per sq. in.	128,000 lbs. per sq. in.
Tensile Strength	155,200 lbs. per sq. in.	163,500 lbs. per sq. in.
Elongation in 2"	17.2 per cent	13.7 per cent
Reduction of Area	55.2 per cent	35.3 per cent
Brinell Hardness	341	348
Izod Impact	36 foot pounds	32 foot pounds
Hardened and Tempered at 1100 Degrees Fahr.		
Yield Point	99,500 lbs. per sq. in.	94,000 lbs. per sq. in.
Tensile Strength	116,000 lbs. per sq. in.	113,000 lbs. per sq. in.
Elongation in 2"	22.1 per cent	17.7 per cent
Reduction of Area	71.7 per cent	52.4 per cent
Brinell Hardness	228	241
Izod Impact	82 foot pounds	42 foot pounds
Tempered at 1425 Degrees Fahr.		
Yield Point	68,000 lbs. per sq. in.	65,000 lbs. per sq. in.
Tensile Strength	88,000 lbs. per sq. in.	87,600 lbs. per sq. in.
Elongation in 2"	30.8 per cent	25.5 per cent
Reduction of Area	73.2 per cent	59.3 per cent
Brinell Hardness	170	170
Izod Impact	96 foot pounds	87 foot pounds

It will be noted that zirconium sulphide reduces the elongation, reduction of area and the impact resistance. There is, however, no indication of brittleness in the new steel at any stage of the heat treatment, and the product treated with zirconium sulphide proves entirely trustworthy for any services within the capacity of its tensile properties.

Grain Growth at Elevated Temperatures

It is well known that stainless iron containing 12.00 to 14.00 per cent chromium is not subject to excessive grain growth when held for a long time at incandescent temperatures. Zirconium sulphide does not in any way alter this property. Fig. 4 illustrates fractures of both steels before and after prolonged exposure to high heat. It will be observed that in neither case has there

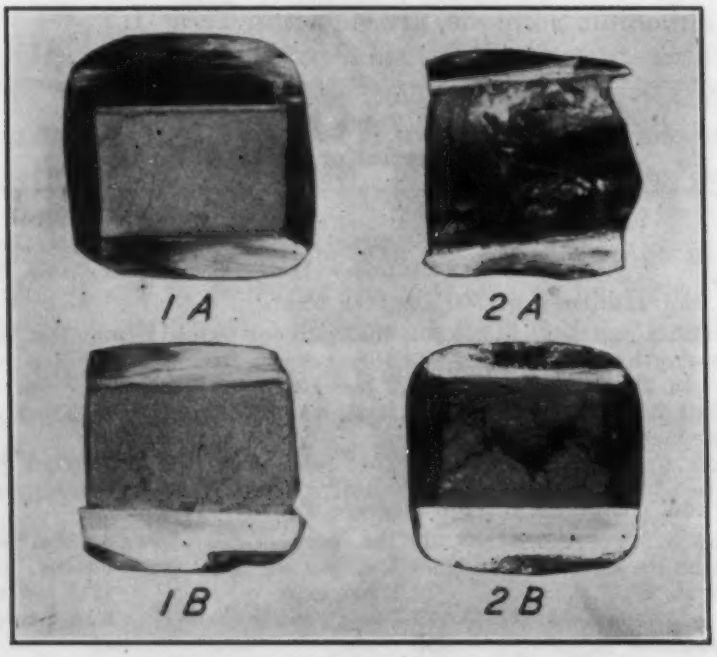

Fig. 4—Photograph of Grain Growth Test Specimens. 1A Stainless Iron Showing Bar Structure Before Test. 1B Stainless Iron After 8 Hours at 1825 Degrees Fahr. 2A Stainless Iron with Zirconium Sulphide Showing Bar Structure Before Test. 2B Stainless Iron with Zirconium Sulphide After 8 Hours at 1825 Degrees Fahr.

been excessive grain growth, in fact there is not as much change as we should expect in a simple carbon steel after this same treatment. All four fractures in Fig. 4 show the structure as quenched. Both steels were too tough to break with a clean fracture in the slowly cooled condition. Structure before the test was secured by quenching in oil from 1800 degrees Fahr. structure after the test was obtained by quenching directly from the eight-hour heat at 1825 degrees Fahr.

Machinability

The presence of 0.40 per cent zirconium sulphide renders

stainless iron just about as freely machinable as common screw stock. This conclusion has been confirmed in dozens of commercial shops which are regularly working ordinary screw stock.

Due to the fact that the chips do not adhere to the tools, the new steel can be drilled, tapped, threaded, broached, reamed and otherwise machined with exactly the same tooling as used for regular shop work.

When machined in the heat treated condition, zirconium sulphide effects the same proportionate improvement all along the

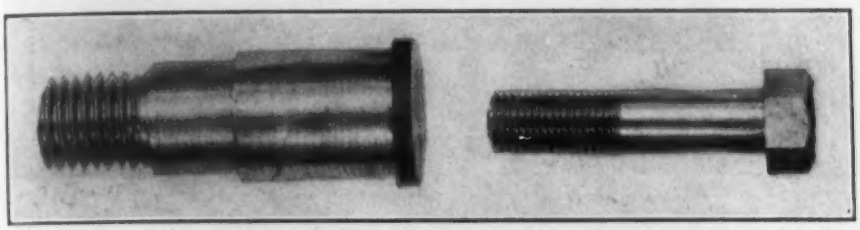

Fig. 5—Illustrations of Production Machining on Stainless Iron Containing Zirconium Sulphide. Details of Machining are Given Below.

line. That is, compared with regular stainless iron, the new steel shows about the same advantage in machinability regardless of the Brinell hardness range being tested.

Fig. 5 illustrates two typical jobs made from stainless iron containing zirconium sulphide. Both of these were machined in strictly screw stock setups. The cap screw is of particular interest because the stock was not soft annealed but was hard drawn to about 235 Brinell. These cap screws having a root area of 0.105 square inches pulled 13,300 pounds average breaking load or 127,000 pounds per square inch. It is almost unbelievable that they could be machined in thirty seconds each.

Screw Machine Part	
Spindle Speed	438 RPM
Die Speed	164 RPM
First Box—Feed	.007 -inch
Second Box—Feed	.005 -inch
Cut-off and Breakdown—Feed	.0016-inch
Stock 1-inch Round Annealed	

7/16-inch Cap Screw	
7/8-inch Grindley Automatic	
Spindle Speed	500 RPM
Box Feed	.0095-inch
Time Each	30 seconds
Stock—5/8-inch Cold Drawn Hex.	
Brinell of Stock	235

Grinding and Polishing

Stainless iron has never been a particularly attractive metal to grind and polish. Gratifying improvement has been effected

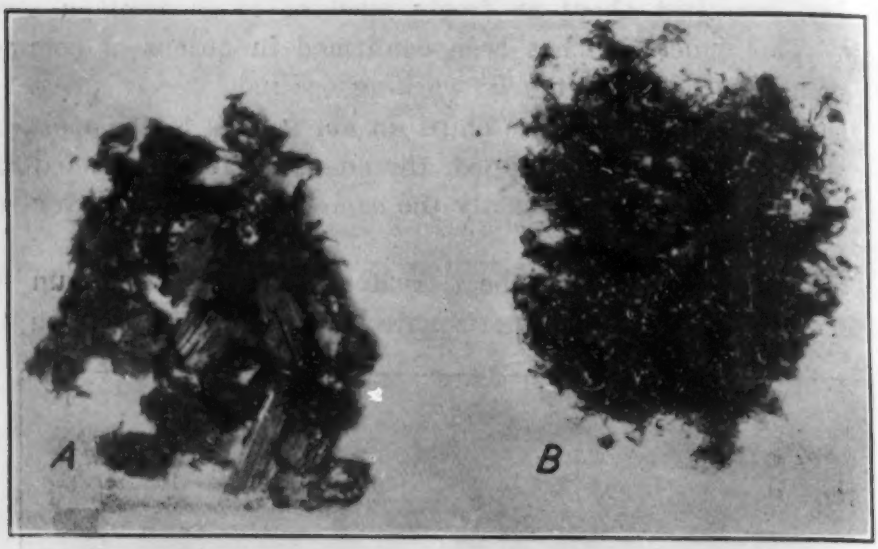

Fig. 6—Photograph of Grinding Chips. A Stainless Iron. B Stainless Iron with Zirconium Sulphide. × 2½.

by careful attention to abrasives and grinding conditions, but there is still much room for improvement. The principal difficulty seems to be due to the steel loading up the wheel and thus interfering with the grits taking hold of the work.

The addition of zirconium sulphide to stainless iron minimizes loading of the wheel and tends to keep the job cool. The steel therefore grinds more rapidly and takes a better finish.

Fig. 6 shows, magnified, the grinding chips from stainless iron and also stainless iron containing zirconium sulphide. Note the large chunks of metal in the stainless iron which have been torn from the work or accumulated by the wheel. The uniform clean-out chips on the other sample almost suggest fine turnings. These chips were produced on a reciprocating surface grinder using a 36-grain wheel with a peripheral speed of 4200 feet per minute.

Anti-Frictional Properties

Several attempts were made to design an accurate and satisfactory test for measuring relative frictional properties. Thus far the attempts have not been successful. It became evident that quantitative results would only be accurate when the samples were prepared with absolutely duplicate surfaces. Since two steels of different frictional tendencies will not take the same finish with

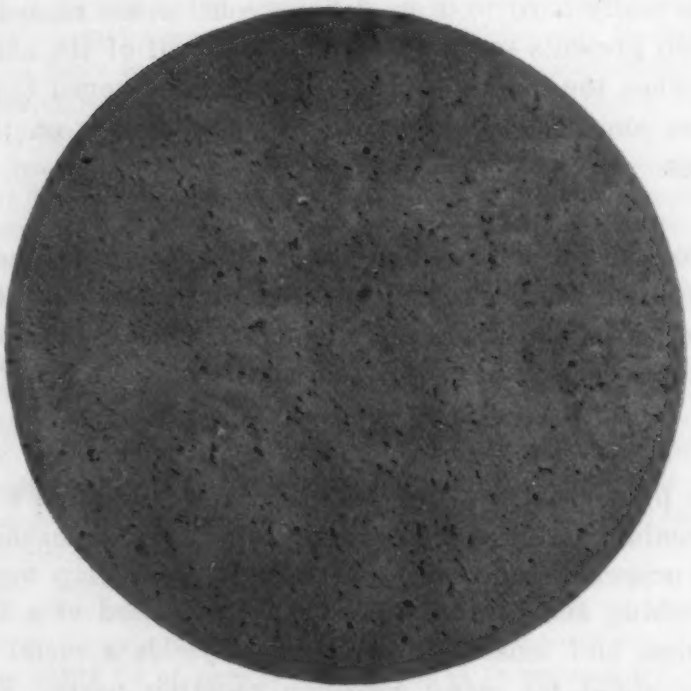

Fig. 7—Unetched Photomicrograph of Stainless Iron with Zirconium Sulphide. × 200.

the same abrasives, the difficulties of duplication can be appreciated. Further work is being done along this line but, in the meantime, some qualitative comparisons taken from commercial application will be of interest.

It has been found that wire made from stainless iron containing zirconium sulphide can be satisfactorily cold drawn without the use of a copper coat. The pressures and temperatures in wire drawing, particularly by the dry process, are quite high and for this reason, the better drawing qualities of the new steel appear to be quite significant.

Machining and grinding have already been mentioned. The superiority of the zirconium treated product appears to hinge largely on the ability of the chips to clear themselves and get out of the way.

Face rings on high-temperature, high-pressure gate valves have shown a slight but definite advantage in favor of zirconium treated material.

Piston rods have been found to wear glossy in packings where stainless iron has a tendency to roughen and scratch.

It is really hard to draw definite conclusions regarding a subject which presents so many variables, but all of the above straws tend to show the direction of the wind. It is hoped that at some later time some quantitative data will be available on the subject of galling.

Microstructure

Zirconium sulphide occurs in stainless iron in the form of minute particles uniformly distributed throughout the steel. Fig. 7 shows a typical section at 200 diameters. These microscopic particles seem to serve as a sort of lubricant.

Conclusions

It is found that 0.40 per cent zirconium sulphide added to a high chromium stainless iron greatly improves the machining and grinding properties, and serves to reduce the tendency toward galling, scratching and seizing. This is accomplished at a slight loss of toughness and tensile properties, but yields a metal which is eminently suited for many corrosion resisting parts. Zirconium sulphide tends to prevent air hardening in the low carbon grades of stainless iron and raises the temperature necessary for hardening.

DISCUSSION

C. L. Frear: There are just two questions I would like to ask the author of this paper. First, I would like to ask if he has done any work on the corrosion resistance properties of this metal containing zirconium sulphide in contact with a regular corrosion resisting steel. I ask this because where two steels, either of which is comparatively corrosion resistant, are used in contact in certain acids, one will become corroded in a very short time due to electrolytic action. We find this occurring often between steels of two different compositions, or even the same steels with different heat treatments.

The second question is whether any work has been done on cold drawing the material which has been rolled into sheets.

Chairman R. M. Bird: Mr. Palmer, do you want to wait until you have collected all the questions or would you prefer to answer those now?

F. R. Palmer: It will be just as well to answer them as they come up.

I suppose the first question refers to galvanic action. I have not investigated any possible galvanic action between the new steel and the old, but since zirconium sulphide is a nonconductor, I imagine it has no effect, however I have never tested it.

The steel can be cold drawn very readily. That is one of the interesting examples of its anti-friction qualities. The older type must be copper-coated

before it can be cold drawn, because if the wire ever touches the die, it will adhere and eventually accumulate in the die until the wire breaks. This type is much less likely to pick up in the die and has been successfully cold drawn in fine sizes of wire and intermediate sizes without any copper coating,—just an ordinary lime coating such as is used with common steel. In sheets there is not much demand for it; it is not a steel that is primarily adapted for making sheets. It has nothing to offer over the base type excepting machinability and grinding properties, and while we might be interested in the grinding of sheets, we do not often machine them, and the older type, on account of its toughness and greater ductility and the ability to deep draw it, is in general, a better material to go into sheets.

A. H. d'ARCAMBAL: Mr. Chairman, I would like to ask Mr. Palmer if he has tried adding zirconium sulphide to other high chromium materials, such as stainless steel and materials of that type. Why would not this addition improve the machinability? Manufacturers of tools are experiencing difficulty daily in attempting to furnish tools that will thread, ream and mill stainless steel, and if you could add zirconium sulphide to some of the other high chromium alloys, it certainly would be very beneficial.

F. R. PALMER: That work is already under way, but it is another story for another day. It does affect equally the machinability of all the chromium ranges which we have investigated, from 8 per cent chromium up to 25 per cent. There are still a lot of corners that remain to be explored but, in general, it seems to have the same effect all along the line.

P. A. E. ARMSTRONG: Zirconium sulphide contains about 15 per cent of metallic zirconium, therefore one half of 1 per cent addition of zirconium sulphide is largely increasing the sulphur content. I would like to ask the author whether zirconium sulphide is a brittle material like iron sulphide at rolling temperatures or whether it is a soft sulphide like manganese sulphide. The author states that sulphur-treated stainless steel does not roll at temperatures above 2100 degrees Fahr. As zirconium sulphide probably begins to melt at 2100 degrees Fahr. the reason why the steel does not roll is apparent. The photomicrographs of the high chromium steel with the zirconium sulphide content shows a large number of small particles very similar to those seen in a dirty steel. Higher magnification would probably show whether or not these particles occurred at the grain boundaries or whether they were just generally dispersed throughout the metal without any relation to its crystalline structure. I should expect to find these sulphide particles occurring at the grain boundaries because they must act in the molten metal as nuclei for crystallizing. Zirconium belongs to a group of metals which have been used extensively in stainless steel and high chromium irons and steels. I am wondering whether a combination of these and other elements with or without sulphur would not accomplish the same result, easy machinability, and whether or not these additional elements which all form sulphide would not dissolve with the iron or dissolve the sulphide in the iron in a better way than appears from the photomicrographs. It so happens that easy machinability of high chromium irons and steels can be obtained by the addition of metallic elements and no use made of the metalloid sulphur. This being the case how much of the advantage of

zirconium sulphide is to be directly attributed to the zirconium rather than the sulphur. Breaking up of the chip and perhaps preventing the tip forming on the machine tool can be attributed to the sulphur. Perhaps the zirconium content itself is preventing the strong adhesion of the chip on the tool point and the sulphur merely breaks up the chip.

DR. R. W. WOODWARD: I have a few questions that I would like to ask Mr. Palmer. In regard to the microstructure of the steel at higher magnifications, I would like to inquire if there were any cubical inclusions discovered. The reason I ask that is, several years ago in working on the effect of zirconium as a metallic alloy in steel, there were encountered at times cubical inclusions, which, at that time, were attributed to zirconium oxide. I would like to inquire if that same feature is observed when zirconium is added as a sulphide.

Mr. Palmer also stated that zirconium sulphide apparently raises the necessary hardening temperature. I am wondering if he has found that it also raised the Ac_3 point to account for the necessary increase in temperature.

In relation to chemical analysis of the steel, I would be interested in learning whether the evolution method of sulphur determination includes the sulphur present as zirconium sulphide.

F. R. PALMER: We do see the cubical crystals but I believe they are zirconium nitride.

I have not made a critical point curve on the material, so I do not know whether the Ac point has been raised or not.

In the evolution method, part of the sulphur is evolved and part is not. The rest must be determined gravimetrically. The percentage evolved varies, it is not always the same.

C. E. MEISSNER: I would like to ask how the addition was made.

F. R. PALMER: I am sorry that I am not in position to answer the question, if you will excuse me.

T. H. NELSON: Mr. Palmer, I think you should be congratulated on the work you have done, because of all the fields that present difficulty in chromium iron, possibly machining, particularly threaded parts, has been the most difficult. It brings to my mind the fact that zirconium has been used for some little time past in conjunction with some of the nickel-chromium alloys and is actually in service with the government in the way of periscope tubes. Zirconium in that condition made machining possible on material on which it was otherwise almost impossible.

What I am wondering is whether this zirconium sulphide is scattered throughout the mass, which is very well brought out by Mr. Palmer, and it is very gratifying along metallurgical lines to see that this evidence is so in order. For instance, his ductility depreciates when his machinability improves, which is quite logical, inasmuch as there is something breaking up the continuity of the material metallographically. Therefore, we have made through Mr. Palmer's discovery a distinct advance in the art of producing machine parts of chromium iron.

Recently I have come across, as a consultant, material which exhibited pin point corrosion, and in that direction I am wondering whether this scattered zirconium sulphide throughout the matrix may not, even microscopically, de-

velop some slight electrolytic action, and whether we have not, in conjunction with Mr. Armstrong's views, other alloys which may give us an opportunity of attaining the same result as our knowledge of this subject progresses. For instance, experiments I have made with tantalum behave somewhat similarly in breaking up the crystalline structure and giving a more free cutting steel.

W. E. GRIFFITHS: I wish to congratulate Mr. Palmer on this very excellent paper and suggest that he answered Mr. Armstrong's question with respect to the fusion point of the zirconium sulphide when he stated that it did not form in the grain boundaries. It is usually found within the grain.

DR. W. H. HATFIELD: Mr. Chairman and gentlemen:—I should like to take this opportunity of saying how much I enjoyed listening to the papers and the discussions, and may I say I have been pleased to see you are taking such a great interest on this side in the heat-resisting and the rust and acid-resisting steels.

I do not think I can make any substantial contribution to the discussion this morning, but there are perhaps one or two observations I might make. I should first of all like to congratulate Mr. Palmer on his command of the subject and the excellent way in which he gave his paper. Of course, the subject of his paper is peculiar to the American industrial world. You go very fast in everything over here, I understand, and, really, this problem which he has set out to deal with has not been found necessary of handling on our side of the Atlantic.

Now, to come to the detailed considerations, Mr. Palmer speaks of the stainless iron sticking to the tool and sticking to the grinding wheel and generally impeding the machining operations. Well, the experience on our side is this, that some people say such material is difficult to machine while others have no difficulty. Now, as Mr. Palmer has already indicated, the geometry of the tool and the selection of suitable feeds and speeds are obviously determining factors in the ease with which a steel can be machined, and I would submit to you gentlemen that even without the zirconium, when you know how to do it, when you know how to machine it, stainless iron, in its properly treated condition, is not particularly difficult to handle. However, no doubt you have that problem on this side and it is very gratifying to find in your range of high velocities that Mr. Palmer has given you a solution that you are so much requiring.

I should be just a little bit more satisfied with the information that has been given if the comparative machining tests had been put forward of the steel not containing zirconium in the same condition as regards hardness and ductility. That is, of course, a feasible test to make.

I was going to ask that question about how the author added this zirconium sulphide. One can visualize how it should be done, but I am rather surprised at a gentleman coming before a scientific society in any country and giving part of his story without giving one of the most interesting parts of it. (Laughter) I think he really ought to be just a little bit ashamed of himself. (Laughter) At any rate, he should so have put the matter forward and so handled the matter in a diplomatic way that he avoided being asked the question and being found out. However, I personally should like to second that

admirable short speech by the gentleman who did ask how this zirconium sulphide was handled.

I do not think I have anything more to say. I really have listened with very great interest to the various papers. I was interested in Dr. Saklatwalla's paper on the attempt to produce steels of an intermediate type between the rust and acid-resisting steels and the ordinary steels, and I hope when I study in more detail the data that those authors have put forward, I shall find that there is an indication in the data to show that there is a possibility of greatly enhancing the corrosion-resisting characteristics of steels without going to the great expense which at present we find absolutely necessary, of putting a lot of chromium in, and, for particular resistance, nickel in addition to the chromium.

Now, may I take this opportunity of making a plea on behalf of, well, I might say the metallurgical world as a whole, and that is this. In Europe and in America we are all equally interested in these special steels. Now, the fundamental tests that we have to put them to are the corrosion tests, and I think it is eminently desirable that we should learn to do our experiments on a common basis and return the results in common values. By common values I mean that our conditions of corrosion tests might well be, as far as possible, standardized and our returns given in similar terms. In England we are endeavoring to arrive at some such basis of that kind, and while I am over here I hope to have the pleasure of meeting many of you gentlemen interested in corrosion. We on our side value and appreciate the excellent work that is being done over here, as I believe you do the work that is being done in Europe. We are working along parallel lines, and if a common basis can be given to the form in which our results are given, it will be of a great advantage to all of us.

JEROME STRAUSS: I would just like to ask Mr. Palmer three questions. First, whether he has observed any lowering of the lower end of the solidification range due to the addition of the zirconium? Second, whether there is any appreciable solubility of the sulphide in the steel in any temperature range? And third, whether there appears to be, microscopically, any association of the sulphide with the carbide?

F. R. PALMER: I have made no observations on the location of the solidification when cooling.

I have seen nothing which leads me to believe that the sulphide is soluble in the matrix. Although it is a pretty hard thing to determine.

I do not think that the sulphide is associated in any way with the carbides. Strangely enough, the steel appears under the microscope as though it were largely delta iron, but judging from its physical properties, it evidently is not.

There is one question which Mr. Nelson asked that I wanted to answer and it slipped my mind when I had the opportunity, and it is extremely important. He brought up the question of isolated spots of corrosion appearing on samples that are tested. Those spots can come from a lot of things, but I want to tell you of one place they may come from where you do not look for

(*Continued on Page 950*)

PRINCIPLES OF THE HEAT TREATMENT OF STEEL
Part III

An Outline Prepared by the Metallurgical Staff of the Bureau of Standards[1]

(*Continued from November issue of* TRANSACTIONS)

CHAPTER VI
CASE HARDENING

The Cementation Process

SO far the principles and processes of heat treatment have been described in respect to steel which has the same carbon content throughout its mass. An important class of steel which is heat treated is *case hardened* or *case carburized steel,* in which the interior is of very low carbon content for toughness, and the exterior is of very high carbon content for hardness and ability to resist abrasion. The process is also called "cementation." The low carbon steel, usually 0.05 to 0.20 per cent carbon, is machined almost to the size of the finished piece desired, embedded in some form of carbon (generally charcoal or other charred carbonaceous matter) mixed with an "energizer" such as barium carbonate which will give off a carbon-containing gas (carbon dioxide), and heated. The carbon dioxide and the solid carbon react, at high temperatures, to form carbon monoxide, another carbon-containing gas which can give up its carbon to the steel, freeing oxygen which in turn combines with the solid carbon to form more carbon monoxide. The carbon monoxide gas thus serves as a carrier to convey carbon from the solid carbon into the steel. It is possible to carburize in suitable gases, and various methods for gas carburization are in use. The heat treatment of steels carburized by such processes does not differ essentially from that of steels carburized with solid carburizing "cements" (pack hardening).

Portions not to be carburized are electroplated with copper or coated with fireclay to prevent access of the gas to those parts. The parts to be carburized are packed in pots together with the carburizing compound, the pots sealed to prevent access of air and the whole slowly heated to the desired temperature and held there long enough for a "case" or high-carbon outer layer of the desired

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thickness to be formed. The temperature and time will depend on the nature of the steel and of the carburizing mixture used. Both have to be carefully chosen to get rapid carburization and to secure a case that grades gradually into the core so the line of demarcation will not be so abrupt that the case will tend to "shell off." Plain carbon steels are much used, but various alloying elements such as manganese, nickel, chromium, vanadium and molybdenum are often used in order to secure a core of the desired properties or to increase the rapidity or the depth of carburizing.

Carburizing of plain carbon steel is carried out at a temperature of about 1650 to 1700 or 1725 degrees Fahr. Whatever the steel, carburizing is generally done at temperatures at which the steel is austenitic, and great care is taken to avoid overheating so as to avoid excessive grain growth of austenite, just as in ordinary heat treatment. It is especially necessary to avoid overheating in carburizing because of the long time required in the process, 5 to 20 hours of heating often being required. Furnaces capable of very good temperature control are therefore necessary to avoid danger of overheating in some stage of the process, and careful pyrometric control is called for. Since some grain growth of the core can scarcely be avoided with such long heating times, further heat treatment is necessary to refine the grain of the core and avoid brittleness.

Heat Treatment of Carburized Steel

While the core is a very low carbon steel, the case is generally mostly of about eutectoid composition, with its exterior going up to perhaps 1 to 1.25 per cent carbon. The range of structure is shown in Fig. 18. By reference to Figs. 10 and 11, it will be seen that the proper normalizing and quenching temperature for the core would be about the same as the carburizing temperature 1600 to 1725 degrees Fahr. depending on the carbon and alloy content, say 1600 to 1650 degrees Fahr. while that for the *case* would be 1400 to 1450 degrees Fahr. If we are not particularly concerned with the structure of the case, we may then merely quench from the carburizing temperature. Since the carburizing temperature is even above the Ac_{cm} of a hypereutectoid case, this quenching from a high temperature tends to distribute the free cementite, (being analogous to a normalizing treatment for high carbon steel). Quenching is frequently followed by a low temperature tempering

Fig. 18 — Section Through Carburized Layer. × 100. The Upper Portion of the Figure Shows the High Carbon Case, the Structure of which is Pearlite and Cementite; the Lower Portion Shows the Low-Carbon Core, the Structure of which is Ferrite and Pearlite. Etchant 5 Per Cent Picric Acid in Alcohol.

(250 to 500 degrees Fahr.) for relief of quenching stresses. This disregards the case and will leave it in its initial condition. A better treatment is to quench twice, first from a high temperature, to refine the *core,* then reheat to 1400 to 1450 degrees Fahr. and again quench to refine the *case.* Since the reheating temperature is below that for formation of austenite of the core, the second quench itself does not affect the grain size of the core, but merely gives the core a high temperature tempering after its first quench. The usual stress-release tempering should follow the second quench.

If the properties of an annealed core are desired, the piece may be cooled in the box, and then reheated to 1400 to 1450 degrees Fahr. and quenched for case refinement, then given a low temperature tempering for stress release. This treatment tends to avoid distortion because of the minimum number of quenchings and the low quenching temperature. Cooling in the box also minimizes oxidation of the surface.

Where distortion is unimportant, the maximum strength and toughness are desired in the core, the piece may first be quenched from the box, then reheated to a lower temperature, 1600 to 1650 degrees Fahr., so as not to exceed the proper temperature for maximum grain refinement of the core, again quenched (finishing the operations aimed at the core), then reheated to 1400 to 1450 degrees Fahr., quenched for refinement of the case, and, as usual, tempered for stress release. Or, the piece may be cooled in the box, to anneal the core, reheated to 1600 to 1650 degrees Fahr. and quenched for core refinement (usually in oil to avoid cracking the case), and, as usual, reheated to 1400 to 1450 degrees Fahr., and quenched for case refinement, followed by the stress-release tempering. The quenching of case hardened carbon steels may be carried out either in oil or water, usually the latter, and if the steel is "abnormal" and prone to give a case with some soft or troostitic spots on quenching, the use of brine may be necessary to give a sufficiently rapid rate of cooling. To avoid distortion and warping during the carburizing process itself, it may be necessary to normalize the piece before it is packed in the carburizing box. The heat treatment of carburized steel is then simply a heat treatment of a duplex low carbon and high carbon steel in which the treatment of the low carbon part precedes the treatment of the high carbon part.

Cyanide and Nitrogen Hardening

A hard, wear resisting surface may also be obtained by immersing the low-carbon steel in molten cyanide (whose poisonousness should never be forgotten). The steel takes up a case, which contains both carbon and nitrogen, from the cyanide. The case is thin and the period of heating short, 10 to 15 minutes at 1550 to 1600 degrees Fahr., and the specimens are quenched from the cyanide bath, usually into limewater so that the lime may neutralize the cyanide left on the steel. Reheating for heat treatment of the case is seldom done, as much of the nitrogen, which helps to harden the case, would be lost on heating. Cyanide cases are rather brittle and tend to flake. If a small spot on the surface is to be hardened, powdered cyanide is sometimes sprinkled on the spot, and the steel is heated to 1550 to 1600 degrees Fahr. and then quenched in water. A non-poisonous compound, calcium cyanamid, dissolved in a molten salt bath is sometimes used for case hardening.

Other methods of surface hardening are being used to some extent in order to avoid distortion from quenching. In these, special steels, often containing chromium and aluminum and sometimes nickel and molybdenum as well, are heated to about 900 degrees Fahr. for a long time in ammonia gas, which forms a thin but very hard and rather brittle nitride case. The core may previously be given any desired heat treatment compatible with the heating involved in the nitrogen hardening process. Chromium plating is also practiced as a substitute for case hardening.

CHAPTER VII

Alloy Steels

Differences Between Carbon and Alloy Steels

The principles of the heat treatment of the various alloy steels are identical with those already discussed for carbon steels and may be directly applied, if all the critical points for the alloy steel to be treated are known.

The introduction of alloying elements changes the eutectoid ratio, the eutectoid of an alloy steel usually being at a lower carbon content than that of a plain carbon steel. With 15 per cent chro-

mium, for instance, the eutectoid is at about 0.30 per cent carbon instead of at about 0.90 per cent. The alloying elements change the critical points on heating; for example, nickel lowers them, silicon raises them. Hence, the temperature to which the steel must be heated before quenching, i.e., to become fully austenitic, is characteristic of that particular carbon and alloy composition.

Some of the alloying elements, especially vanadium, decrease the grain growth of austenite and the rate of carbon diffusion in austenite and may not only allow but require higher temperatures for quenching than with carbon steels. With nickel, on the other hand, the temperature is notably lowered. When two or more alloying elements are present, the resulting properties of the steel are a balance among those conferred by the different elements.

Quenching Rates

One of the outstanding effects of most alloying elements is to make austenite sluggish, i. e., to make it require a less rapid rate of cooling in quenching to harden to martensite. Hence, alloy steels can be had that will harden to the center in air, oil or water, in sizes where a carbon steel would only harden on the surface or not at all, in the same medium. Manganese, nickel, chromium and molybdenum are especially active in lowering the critical cooling rate for hardening.

The temperatures (Ar′ and Ar″) at which troostite and martensite form on quenching are also changed by the different alloying elements. On account of this effect upon the rate of cooling necessary to harden, there is, with most alloying elements, a range of relatively low carbon and alloy contents in which air cooling or normalizing produces a pearlitic steel, just as it would in carbon steels. At higher carbon and alloy contents there is a range of compositions in which the steels are air hardening, i.e., become martensitic on air cooling. At still higher carbon and alloy contents the steel may remain austenitic down to room temperature and thus not be amenable to heat treatment. An example of this is the austenitic manganese steel of 12 per cent manganese and 1 per cent carbon. Another is the class of nickel-chromium steels which may contain about 18 per cent chromium and 8 to 25 per cent nickel.

According to many observations, in quenching some alloy

steels more austenite is obtained by oil quenching, than by drastic water quenching, provided the other quenching conditions remain the same.

In the light of our knowledge of the large internal stress set up in steel by the quenching process it appears conceivable that within some regions of a piece of quenched steel these stresses may exceed the elastic limit of any austenite existing at the time, thus producing deformation of the tiny patches of austenite. The severity of the water quench would probably cause the stress to exceed the elastic limit throughout a much greater extent of the specimen than the oil quench. Inasmuch as a deformed austenite (as observations show) is rendered less stable on cooling or on heating it may be expected that more austenite is transformed into martensite in water quenched alloy steels than is the case in oil quenched steels.

Tempering Temperatures

Not only do the alloying elements alter the critical points and the hardening power of steel, but they affect the rate of tempering after hardening. Molybdenum steels, in particular, require much higher tempering temperatures to soften the hardened steel, i. e., to break martensite down into troostite and troostite into sorbite, than are required for carbon steels. The alloying elements may also have an effect by altering the nature of cementite. Instead of the cementite consisting only of iron carbide with a little manganese carbide as in ordinary carbon steels, the cementite of alloy steels may contain also the carbides of chromium, vanadium, tungsten and molybdenum. These carbides are made use of in many types of alloy tool steels where they form tiny "teeth" in cutting tools, and the properties of the tools depend on the hardness and brittleness, etc., of the "teeth." Other alloying elements like nickel do not form carbides, but go into solution with the ferrite, toughening it.

The heat treatment of an alloy steel, in spite of these various different effects due to the different alloying elements, may be resolved into fundamental factors exactly similar to those for the treatment of the carbon steels, and while it is necessary to consult data for each particular type and composition of alloy steel in order to decide upon the proper heat treatment for it, the fundamental principles are exactly the same.

Because each alloy steel can, by proper heat treatment, be given

a wide range of properties, various steels may, after each has been given the proper heat treatment, be used for similar purposes so that, by virtue of heat treatment, there exist a number of different usable steels for any particular purpose, and a choice may be made on the score of cost, of suitability to the heat treating equipment available, to the particular machining problems involved, and to other factors due to the requirements of the product or the plant conditions.

CHAPTER VIII

High Speed Tool Steel

Composition

The amount of alloying elements in high speed steel is so large that on air cooling small sections from high temperatures the steel is partly martensitic and partly austenitic and becomes harder on tempering due to the transformation of some of the austenite into martensite (secondary hardening). The eutectoid ratio is reduced by the large amounts of alloying elements, and hence the steels are hypereutectoid and contain free carbides and other hard particles in the annealed condition.

The service to which high speed steel is put requires a material which will retain its hardness at the high temperatures generated at the cutting edges of the tool by the friction of cutting. The composition and treatment of the steel are selected to produce the special compounds that have this property of remaining hard at red heat. For example, the relatively large amount of tungsten present serves to obstruct the transition of austenite to pearlite, to hold the steel in the martensitic condition, and to impart additional hardness through the formation of the double carbide of tungsten and iron. The heat treatment of high speed tool steel, on account of the large amount of alloying elements present and the special requirements of the product, differs radically from that of other types of steels.

To get the correct distribution of the carbides, tungstides, etc., in the heat treated steel, high speed steel has to be heated very much hotter before quenching than other type of steels. Proper solution and diffusion of these compounds in austenite, without too great

grain growth, is very important, and the most important of the steps in the heat treatment of high speed steel is the heating for quenching, the time and temperature requiring the strictest control. To prevent cracking from too rapid heating, the steel has to be preheated at a lower temperature in a separate furnace before being put in the second furnace for its final high temperature heating.

The essential alloying elements in modern high speed tool steels are chromium and tungsten. However, practically all brands produced in this country for tools contain also between 0.50 and 2.25 per cent vanadium. The high speed steels are usually classified according to the tungsten and vanadium contents, and they may be grouped under headings as follows:

1. Low-tungsten and high-vanadium type.
2. High-tungsten and low-vanadium type.
3. Special steels.

The approximate chemical compositions of groups 1 and 2 are as follows:

Per Cent	Low-tungsten and high-vanadium	High-tungsten and low-vanadium
Carbon	0.60 to 0.75	0.60 to 0.75
Tungsten	11.50 to 14.00	17.00 to 18.50
Chromium	3.25 to 4.25	3.25 to 4.25
Vanadium	1.75 to 2.25	0.60 to 1.25
Manganese	0.35 max.	0.35 max.
Silicon	0.35 max.	0.35 max.
Phosphorus	0.030 max.	0.030 max.
Sulphur	0.030 max.	0.030 max.

Modifications in the chemical composition of either group 1 or 2 or the addition of certain other elements such as cobalt (which is the most important of this group), molybdenum, uranium, etc., constitute the third group called the special steels.

Forging

High speed tool steels should be forged at high temperatures, never at a dark red, else the tools will be prone to crack on treating. All forged high speed steel tools should be annealed before hardening to relieve forging strains.

Annealing

Before heating for quenching, the steel should be annealed by heating slowly and uniformly to a temperature of 1600 to 1650 degrees Fahr. and holding to insure uniformity of grain. Time at temperature will vary with the steel and section but should ordinarily not be less than 1 hour for ¼ inch metal thickness. Cooling should be done in the furnace or in some medium which will permit uniform slow cooling.

Annealing is best done in a closed container in the presence of a little charcoal to render the atmosphere less oxidizing and thus reduce scaling.

Hardening

For hardening, the annealed steel is preheated slowly and uniformly to 1450 to 1650 degrees Fahr. to prevent cracking, next heated very rapidly to about 2250 to 2400 degrees Fahr., held just long enough for the working portions of the tool to attain the desired solution of carbides, etc., and then cooled in oil, in air, or in an air blast. The hardening temperature and method of cooling will vary with the composition of the steel, the type of tool, and the service for which the tool is used.

The life of high speed steel tools when subjected to severe conditions of cutting or so-called roughing conditions is affected to a marked degree by the "high heat" temperature used in hardening. The life rises rapidly with increase in temperature above 2200 degrees Fahr. However, a point is finally reached where a further increase in hardening temperature is no longer attended by a commensurate increase in the life. If too high a temperature is employed, a decrease in the life will take place coincident with a partial melting of the tool. There is a "critical" high temperature which results in maximum life, but this varies with the composition. It is higher in the high-tungsten and low-vanadium type than in the low-tungsten and high-vanadium type, and it is raised in both types by the addition of 3 to 5 per cent cobalt. The life of high speed steel tools under heavy duty conditions also depends upon the time that the tool is at the high temperature in the hardening operation. Therefore, for consistent results both time and temperature should be controlled by suitable instruments. A strongly oxidizing furnace atmosphere should be avoided.

Tempering

For tempering, the hardened steel is heated in a furnace or molten bath to a temperature of 1000 to 1100 degrees Fahr. for a sufficient time to allow the tool to reach a uniform temperature throughout. Cooling may be in air or oil. High speed steel tools subjected to severe service have a life characteristic of the high-temperature treatment used in hardening and the life is not modified to any great degree by subsequent tempering up to 1020 to 1110 degrees Fahr. However, the higher the tempering temperature the tougher will the tool become. Thus, one of the most important reasons for tempering is not the increase in tool life but a decrease in brittleness. As the reaction of the high-speed steels to time-temperature changes is sluggish, it is sometimes necessary to heat for long periods (5 or more hours for small sections) to realize the full benefits of tempering.

In normal shop practice so-called "flaky" high speed steel which shows variable brittleness may be produced through the hardening of long lengths of lathe or planer tools, followed by dressing operations in which only part of the previously hardened tool is heated to annealing temperatures. Prevention of the formation of the flaky structures in high speed steel in heat treatment is much more simple than its elimination and may be accomplished by annealing between successive hardening treatments. "Flake," once produced, can frequently only be eliminated, by reforging, followed by annealing.

CHAPTER IX

Heat Treatment of Other Alloys

Many other alloys beside steel may be heat treated. The annealing of cold-worked metals is necessary in the rolling, drawing or other working of the nonferrous metals and alloys. Some of the alloys, notably the aluminum alloys of the duralumin type, lead-antimony alloys, and copper-silicon alloys may be hardened by quenching and tempering (or aging) in a manner quite similar to the hardening of steel. The ability of these alloys to be heat treated depends on the ability of some constituent to be taken into solid solution on heating, retained in solid solution by quenching and

then precipitated in controlled fashion, by reheating, or spontaneously upon aging.

Sources of Further Information—Books

Heat Treating Furnaces

Because the success of heat treating operations depends so much on correct heating conditions the correct design and operation of furnaces play an important part in heat treatment. Continuous, automatic, furnaces with the heating cycle automatically controlled not only as to temperature but as to time are finding much use. References to literature dealing with furnaces and their control will be found in the periodical bibliography, page 912.

The standard book on the subject is—

1. Industrial Furnaces, Trinks, W., Vol. I, p. 308 (1923), and Vol. II, p. 389 (1925), Vol. I, $5.50, Vol. II, $4.50; American Society for Steel Treating, Cleveland.
   (See also references (67, 43).

Pyrometers

The proper choice, maintenance and use of pyrometers is likewise essential in heat treatment. These matters are discussed in many of the books on metallography (page 909), in references given in the periodical bibliography (p. 923), and in the following books:

2. Pyrometry—Wood, W. P., and Cook, J. M., 1927, 207 pp., American Society for Steel Treating, Cleveland, $3.00.
3. Pyrometry—Fairchild, C. O., Chapter in volume I, Handbook on Nonferrous Metallurgy, Liddell, D. M., 1926, volumes 1 and 2, American Society for Steel Treating, Cleveland, $12.00.
4. Pyrometric Practice, Foote, P. D., Fairchild, C. O., and Harrison, T. R., Bureau of Standards Technologic Paper No. 170. 1921, 326 pp. Superintendent of Documents, Washington, D. C., 60 cents, stamps not accepted.
5. Measurement of High Temperatures—Burgess, G. K., LeChatelier, H., 1912, 3d Ed., 510 pp., American Society for Steel Treating, $4.00.
6. Practical Pyrometry, Ferry E. S., Shook, G. A., and Collins, J. R., 1917, 147 pp., American Society for Steel Treating, Cleveland, $1.50.
7. Symposium on Pyrometers and Pyrometry, *Transactions*, Faraday Society (London), Vol. 13, Pt. 3, May, 1918, 170 pp.
8. Pyrometry Symposium—American Institute of Mining Engineers, 29 West 39th St., New York, 1920, 701 pp.
9. American Society for Steel Treating Handbook.
   Information will also be found in reference 1.

Thermal Analysis

The determination of the critical ranges in steel is discussed in many of the books on pyrometry listed above, and is also generally dealt with in books on metallography (p. 909). References to periodical literature will be found on page 923. Other references are:

10. Metallographic Researches, Benedicks, C., 1926, 207 pp., A. S. S. T., $4.00.

BUREAU OF STANDARDS PAPERS*

11. Scientific 213, Critical Ranges A_2 and A_3 of Pure Iron, 1913, 56 pp., 20 cents.
12. Scientific 296, Thermoelectric Measurement of Critical Ranges of Pure Iron, 1916, 7 pp., 5 cents.
13. Scientific 336, A Simplification of the Inverse-rate Method for Thermal Analysis, 1919, 4 pp., 5 cents.
14. Scientific 348, Use of a Modified Rosenhain Furnace for Thermal Analysis, 1919, 7 pp., 5 cents.
15. Technologic 230—A Recording Chronograph for the Inverse Rate Method of Thermal Analysis, 1923, 11 pp., 5 cents.

Mechanical Testing of Heat Treated Steels

The testing of heat treated steels by mechanical methods, for tensile strength, ductility, hardness, torsional strength, endurance limit, etc., is discussed in various books mentioned below, as well as in the Transactions of such societies as the American Society for Testing Materials, American Society of Mechanical Engineers and Society of Automotive Engineers.

Books

16. The Fatigue of Metals, H. F. Moore and J. B. Kommers, 1927, 326 pp., American Society for Steel Treating, Cleveland, $4.00.
17. Manual of the Endurance of Metals Under Repeated Stress, H. F. Moore, Engineering Foundation, New York, pub. No. 13, 1927.
18. The Fatigue of Metals, H. J. Gough, 1924, pp. 304, American Society for Steel Treating, Cleveland, $10.00.
19. Text Book of the Materials of Engineering, H. F. Moore, 1920, 2d Ed., pp. 315, American Society for Steel Treating, Cleveland, $3.00.
20. Johnson's Materials of Construction—Rewritten by M. O. Withey and James Aston, 1919, 840 pp., American Society for Steel Treating, Cleveland, $6.00.
21. American Society for Testing Materials, A. S. T. M. Standards, 1927, Part I—Metals.
    Page 804, Standard Methods of Brinell Hardness Testing of Metallic Materials.

*These are available from the Superintendent of Documents, Washington, D. C., at prices shown, stamps not accepted.

(Serial Designation E-10-27).
Page 793, Standard Methods of Verification of Testing Machines.
(Serial Designation E-4-27).
Proceedings, American Society for Testing Materials, Vol. 27, 1927, Part I.
Page 1067, Tentative Methods of Tension Testing of Metallic Materials.
(Serial Designation E-8-27T).
Page 1081, Tentative Methods of Compression Testing of Metallic Materials.
(Serial Designation E-9-27T).

22. Materials of Construction, Mills, A. P., 1922, 2d Ed. 489 pp., American Society for Steel Treating, Cleveland, $4.00.
23. Mechanical Testing, R. G. C. Batson and J. H. Hyde, E. P. Dutton and Co. (1922-23).
24. The Testing of Materials of Construction, W. C. Unwin (1910), 480 pp., American Society for Steel Treating, Cleveland, $5.00.
25. Materials of Construction, G. B. Upton (1916), 327 pp., American Society for Steel Treating, Cleveland, $3.00.
26. Strength and Structures of Steel and Other Metals, W. E. Dalby, American Society for Steel Treating, Cleveland, $7.00.
27. Applied Elasticity, S. Timoshenko and J. M. Lessells, 544 pp., American Society for Steel Treating, Cleveland, $6.00.
28. Society of Automotive Engineers, 29 West 39th Street, New York City.
Society of Automotive Engineers' Handbook (Revised annually).
Part VII—Test Specimens, S. A. E., Standards.
Part VIII—Hardness Tests, Recommended Practice.
29. American Society for Steel Treating Handbook.

Metallographic Testing

The use of the microscope both for routine testing and control and for purposes of investigation is discussed in many of the books on heat treatment as well as in those primarily dealing with metallography. References are given in the periodical bibliography (page 923).

30. Metallography and Heat Treatment of Iron and Steel, A. Sauveur, 3d Ed., 1926, 535 pp. (A standard text book), American Society for Steel Treating, Cleveland, $8.00.
31. Practical Microscopical Metallography, R. H. Greaves and H. Wrighton, 1924, 125 pp., American Society for Steel Treating, Cleveland, $5.00.
32. Metallography, C. H. Desch, 3d Ed., 1922, 435 pp. (A standard text book), American Society for Steel Treating, $5.00.
33. An Introduction to the Study and Metallography and Micrography, L. Guillet and C. Portevin,—translated by L. Taverner, 1922, 289 pp., American Society for Steel Treating, Cleveland, $6.00.

34. Bureau of Standards Circular 113, Structure and Related Properties of Metals, 1921, Superintendent of Documents, Washington, D. C., 25 cents, stamps not accepted.
35. Metallography, Vol. I, and II, S. L. Hoyt, 1920 and 1921, 256 and 462 pp. (Exceptionally clear and good—a standard text book), American Society for Steel Treating, Cleveland, Vol. I, $3.00; Vol. II, $5.00.
36. Metallography of Steel and Cast Iron, H. M. Howe, 1916, 641 pp. (A standard reference book), American Society for Steel Treating, Cleveland, $10.00.
37. Introduction to Physical Metallurgy, W. Rosenhain, 1915, 335 pp., American Society for Steel Treating, Cleveland, $4.00.
38. Structural Metallography, H. B. Pulsifer, 1924, 210 pp., Chemical Publication Co., Easton, Pa.

Specifications and Recommended Practice

Specifications for certain heat treated products are issued by the War Department, Navy Department, American Society for Testing Materials and Society of Automotive Engineers.

Recommended practice as to the heat treatment suggested to meet specifications, or for particular products, may be found in the TRANSACTIONS and the HANDBOOK of the American Society for Steel Treating and to a lesser extent, in the publications of the American Society for Testing Materials and the Society of Automotive Engineers.

Sources of Fuller Information on Heat Treatment

The foregoing account of the principles involved in the heat treatment of steel is by no means complete, and is intended only as an introduction to larger treatises. The subject is so complex that the student will be well repaid if, before going on to the study of more detailed descriptions of the principles and processes of heat treatment, he will first study two or three of the shorter publications which cover much the same ground as does this outline. Each author is likely to take for granted that his reader grasps his initial presentation of any new point and then to go on to an argument depending on that point.

If the same facts, presented from different points of view by different writers, are read in different publications, the fundamentals with which all the writers deal will become clearer to the reader. Such apparent duplication is more necessary when a reader is working on the subject at home and has no opportunity to discuss with experts points that are not clear, as he may do when studying the subject in a technical school.

Elementary Discussions

Two relatively brief elementary discussions of the principles of heat treatment are recommended for introductory reading. It should be remarked

at the outset that a mere rapid reading of these books will not suffice. The principles of heat treatment involve so many factors that only after continued study can these factors be learned, remembered and applied.

39. Elements of the Heat Treatment of Steel, French, H. J., *American Machinist*, Vol. 55, Dec. 8 and 15, 1921, pp. 907, 960 (9 pp.), McGraw Hill Publishing Company, New York City.
40. The Heat Treatment of Steel, Foley, F. B., Articles in *Fuels and Furnaces*, Vol. 2, No. 9, Sept., 1914, p. 889 (46 pp.), published by F. C. Andresen and Associates, 706 House Bldg., Pittsburgh, Pa. (A good introduction to the subject).
41. Heat Treatment of Steel, Boylston, H. M., *Fuels and Furnaces*, Vol. 4, No. 9, Sept., 1926, p. 1035 (31 pp.).
42. The Heat Treatment of Metals, Lanham, E. T., and Irvine, A. S., 1926, 100 pp. (Written to accompany a laboratory course in heat treatment), American Society for Steel Treating, Cleveland, $3.00.

Other books dealing in an elementary or relatively non-technical manner with the principles of heat treatment are:

43. Heat Treatment, Its Principles and Applications, Fulton, C. H., Henton, H. M., and Knapp, J. H. (95 pp.), 1924, American Society for Steel Treating, Cleveland, $2.00.
(This also appeared in serial form in *Iron Trade Review*, Vol. 73, 1923).

This is one of the clearest, short but quite complete, descriptions of the subject. A chapter on heat treating furnaces is included.

44. Principles of Metallurgy of Ferrous Metals, Cammen, L., 2d Ed., 1926, Chapter 4 (23 pp.). (Total pages 145), American Society for Steel Treating, Cleveland, $2.00.

The other chapters will also be of interest. The book is written from the mechanical engineer's point of view rather than that of the metallurgist.

45. Non-Technical Chats on Iron and Steel, L. W. Spring, 1927, 2d Ed., 465 pp., American Society for Steel Treating, Cleveland, $4.00.

Chapters dealing with heat treatment in its relation to materials of construction are found in the books mentioned under mechanical testing and metallography, especially numbers 19, 20, 21, 25, 30, 32, 35, 36, 37.

46. Iron and Steel—(A pocket encyclopedia) Tiemann, H. P., 1919, pp. 211-233 (22 pp.). Total pp. 514, American Society for Steel Treating, Cleveland, $4.00.
47. Kent's Mechanical Engineers Handbook, Kent, R. T., 1923, 10th Ed., pp. 425-431, 449-454, American Society for Steel Treating, Cleveland, $6.00.
48. Mark's Mechanical Engineers Handbook, Marks, L. S., 1924, Ed., pp. 471-523, American Society for Steel Treating, Cleveland, $6.00.

Text Books

Text books dealing with heat treatment of steel as well as of the manu-

facture of iron and steel, or dealing with heat treatment of steel as one part of the metallurgy of both ferrous and nonferrous alloys, are given above under metallographic testing. Others are—

49. Metallurgy of Iron and Steel, Stoughton, B., 1923, Chapter 15, American Society for Steel Treating, Cleveland, $4.00.
50. The Science of Metals, Jeffries, Zay, and Archer, R. S., 1924, 460 pp., American Society for Steel Treating, Cleveland, $5.00.
(Deals especially with the principles of grain growth and of hardening. One of the most important text books).
51. Iron and Steel, Boylston, H. M., 1928, pp. 494-561, American Society for Steel Treating, Cleveland, $5.00.

Books dealing in considerable detail with heat treatment and, as well, with factors in the making of steel that have a bearing on its behavior in heat treatment are:

52. The Making, Shaping and Treating of Steel, Camp. J. M., and Francis, C. B., 4th Ed., 1925, Pt. 3, 174 pp. (Total pp. 1142), published by Carnegie Steel Company, Pittsburgh, Pa. Price, $8.00.
(This book covers all phases of the steel industry in a clear fashion. It is a very useful reference book).

A book dealing in particular with heat treatment of steel castings is:

53. Heat Treatment of Soft and Medium Steels, F. Giolitti, 1921. (Translated by Thum, E. E., and Vernaci, D. G. (374 pp.), American Society for Steel Treating, Cleveland, $5.00.

Two series of articles, not yet available in book form, but to be published as books later, have appeared in the TRANSACTIONS of the American Society for Steel Treating, 7016 Euclid Ave., Cleveland, in the last few years.

54. Constitution of Steel and Cast Iron, Sisco, F. T., TRANSACTIONS, American Society for Steel Treating, 1926-1928.
55. Facts and Principles Concerning Steel and Heat Treatment, Knowlton, H. B., TRANSACTIONS, American Society for Steel Treating, 1925-28, especially Vol. 11, 1927, p. 450, Vol. 12, 1927, pp. 106, 478, 791.
(Both series are written in simple style and from the practical point of view).

A rather similar series of articles forming a text book for use in the night course given at and the correspondence course given by Temple University, Philadelphia, is by H. C. Knerr.

56. Knerr, H. C., Forging-Stamping and Heat Treating, 1924-28 (now Heat Treating and Forging), 108 Smithfield St., Pittsburgh, Pa.

Books dealing primarily with heat treatment are:

57. Heat Treatment of Tool Steel, Brearley, H., 2d Edition, 207 pp. 1911, American Society for Steel Treating, Cleveland, $5.00.
58. Working of Steel, Annealing, Heat Treating and Hardening of Carbon and Alloy Steel, Colvin, F. H., and Juthe K. A., 1921, 246 pp., American Society for Steel Treating, Cleveland, $3.00.

59. Steel Thermal Treatment, Urquhart, J. W., 1927, 2d Ed., 352 pp., American Society for Steel Treating, Cleveland, $8.00.

60. Steel and Its Heat Treatment, 3d Ed., 1918 (165 pp.), published by Metallurgical Staff, E. F. Houghton and Company, Philadelphia, Pa.

61. Practical Metallurgy for Engineers, 1st Ed., 1923, 431 pp., published by E. F. Houghton and Company, Philadelphia, Pa.
(Although the titles differ, the latter of these last two covers about the same ground as the former).

Other publications dealing with the subject from the metallographic point of view, which have some comment on principles of heat treatment, are:

62. Metallurgy, Wysor, H., 1927, pp. 380-398, Chemical Publishing Company, Easton, Pa.

63. Microscopic Examination of Steel, Navy Department, 1916, October, Ordnance, Pamphlet No. 403.

64. Microstructure of S. A. E. Steels After Recommended Heat Treatments, Sauveur, A., and Reed, E. L., 1927, American Society for Steel Treating, 7016 Euclid Avenue, Cleveland.
(A chart, with 166 reproductions of micrographs of structure). $10.00.

65. The Physico-Chemical Properties of Steel, Edwards, C. A., 2d Ed., 1920, Chas. Griffin & Co., London (280 pp.).

66. The Metallography of Steel and Cast Iron, Woodward, W. E., 1926, Crosby Lockwood and Son, London, 143 pp.

67. Steel and Its Heat Treatment, Bullens, D. K., 3d Ed., 1927, 564 pp., American Society for Steel Treating, Cleveland, $5.00.
This is the latest, most complete book on the subject, and while intensely practical, clearly brings out the theory and principles involved and the way they are applied. It should be in the library of every steel treater. It deals both with carbon and alloy steels.

68. The Steel Foundry, Hall, J. H., 1922, Chapter 9, pp. 273-316. (Total pp. 334), American Society for Steel Treating, Cleveland, $5.00.
(Contains a discussion of heat treatment of steel castings).

Alloy Steels

Another extremely useful book, dealing largely with alloy steels, but also with the general principles of heat treatment is:

69. Engineering Steels—Aitchison, L., 1921, 397 pp., American Society for Steel Treating, Cleveland, $6.00.
(This is of special value in the problem of the choice of steels for different engineering uses).

Another book written from a similar point of view, but dealing especially with molybdenum steels which were not dealt with by Aitchison is:—

70. Molybdenum, Cerium and Related Alloy Steels, H. W. Gillett and

E. L. Mack, 1925, The Chemical Catalogue Co., Inc., New York City, 300 pp.

A report on properties of carbon and alloy steels after different heat treatments, and dealing especially with the "mass effect," is:—

71. Report of the Steel Research Committee, British Engineering Standards Association, October, 1920, published by J. W. Northend, Ltd., West St., Sheffield, England.

Commercial Booklets

Much useful information on alloy steels and their treatment as well as data bearing on the heat treatment of carbon steel can be obtained from booklets put out by firms that produce or sell alloy steel.

Mechanical Properties

The mechanical properties of steels corresponding to the Society of Automotive Engineers specifications are given in the S. A. E. Handbook (see reference 29), and (reference 83).

72. Bureau of Standards Circular No. 101, Physical Properties of Materials—available from Superintendent of Documents, Washington, D. C., for 40 cents, stamps not accepted.

Case Hardening

73. Case Hardening of Steel, Brearley, H., 1914, 170 pp., American Society for Steel Treating, Cleveland, $6.40.
74. The Cementation of Steel, Giolitti, F., Translated by Richards, J. W., and Roullier, C. A., 407 pp., 1915, American Society for Steel Treating, Cleveland, $5.00.

APPENDIX B

Sources of Further Information—Current Publications

Technical Societies

The American Society for Steel Treating, 7016 Euclid Avenue, Cleveland, issues its Transactions monthly. It issues a handbook containing recommended practices on such subjects as heat treatment of plain carbon steel, carbon tool steel, high speed steel, oil-hardening tool steel, finishing steel, taps and milling cutters, die blocks, spring steel, magnet steel, etc.; carburizing and heat treatment of carburized steels, gears, cam shafts, piston pins, selective carburization, iron-carbon diagram, stainless steel, nickel and nickel-chromium, tungsten, vanadium, and molybdenum steels; pyrometry, preparation and etching of metallographic specimens, photomicrography, hardness tests, tensile and other test specimens, cutting tests of tool steels, S. A. E. specifications, coloring steel articles, electric furnace efficiencies, lead baths,

fuels, fuel consumption, corrosion of iron and steel, salt baths, cast iron, clay firebrick shapes, forging, etc.

A list of the reprints of articles printed in the TRANSACTIONS with prices, can be obtained from the Society.

The Society of Automotive Engineers, 29 West 39th Street, New York City, issues data sheets on the properties of the S. A. E. steels. Its *Bulletin* and *Transactions* contain some articles of interest.

The American Society for Testing Materials, 1315 Spruce Street, Philadelphia, Pa., issues specifications, and its annual *Proceedings* contain articles on testing and research.

The *Transactions* of the American Society of Mechanical Engineers, 29 West 39th Street, New York City, contain some articles related to heat treating and heat treated products.

The American Institute of Mining and Metallurgical Engineers, 29 West 39th Street, New York City, issues separate pamphlets on the metallurgy of iron and steel, a monthly periodical *Mining and Metallurgy* and its *Transactions*. Information dealing with heat treatment is found in these publications.

Abstracts of current literature on heat treatment are issued in publications of all these societies except the American Society for Testing Materials.

The British Iron and Steel Institute, 27 Victoria St., London, S. W. I., England, issues its *Journal* twice a year, which contains original articles and abstracts of current literature.

The American Iron and Steel Institute, 61 Broadway, New York City, issues an annual year book.

The American Electrochemical Society, Columbia University, New York City, issues *Transactions* twice a year in which some articles of interest to heat treaters, especially on electric furnaces, may appear.

Abstracts

Chemical Abstracts are published by the American Chemical Society, Mills Bldg., Washington, D. C., and *Science Abstracts* are published by Spon and Chamberlain, 120 Liberty Street, New York City.

Industrial Arts Index is published by H. W. Wilson Company, 960 University Ave., New York City. All carry abstracts or references to current articles on heat treatment.

Periodicals

Journals dealing on a whole or in part with heat treating, not issued by technical societies, are:

Iron Age, 239 West 39th Street, New York City.
Iron Trade Review, Penton Publishing Co., Cleveland.
Heat Treating and Forging (formerly Forging-Stamping and Heat Treating), published by Steel Publications Inc., Pittsburgh.
Fuels and Furnaces, House Bldg., Pittsburgh.
Iron and Steel World, House Bldg., Pittsburgh.

Government Publications

The Bureau of Standards and Bureau of Mines, both of the Department of Commerce, Washington, D. C., carry on experimental work dealing with the production and heat treatment of steel. Lists of their publications will be sent on request, and the official publications of these Bureaus may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Foreign Periodicals

Important foreign periodicals carrying articles on heat treatment are:

Revue de Metallurgie,	5 Cite Pigalle, Paris, France.
Engineering	35 Bedford St., Strand, London, W. C. 2, England.
The Engineer (also *Metallurgy,* a monthly supplement)	33 Norfolk St, Strand, London, W. C. 2, England.
Stahl und Eisen	27 Breite Strasse, Dusseldorf, Germany.

APPENDIX C

Facilities for Study of Principles and Practice of Heat Treatment

Suggested Course for Home Reading

It is believed that a careful study of the following books, in about the order given, will give the student a useful understanding of the principles and practice of heat treatment:

French (39)
Fulton-Henton-Knapp (43)
Foley (40), or Lanham and Irvine (42).
The American Society for Steel Treating Handbook
Knowlton (55)
Sisco (54)
or
Knerr (56)
Aitchison (69)
Camp and Francis (52)
or
Boylston (51)
Bullens (67)
Hoyt (35)
Sauveur (30)
Howe (36)
Jeffries and Archer (50)

Such a course of study should put the student in a position to understand even the more technical articles dealing with heat treatment in current journals.

If library facilities are not available and the student can only invest a little money in a technical library, he can get much information at small cost in the following:

> Fulton-Henton-Knapp (43), American Society for Steel Treating Handbook, Bullens (67), and by joining the American Society for Steel Treating, so as to get the current TRANSACTIONS.

Correspondence Courses

It will often be easier for a student to work on a definitely laid out course of study than to depend solely on reading a series of books. Correspondence courses dealing in especial detail with heat treatment and metallography are the Sauveur and Boylston Correspondence Course, 2083 Taylor Road, East Cleveland, Ohio, and one given by H. C. Knerr, 1500 Green St., Philadelphia.

The International Correspondence Schools, Scranton, Pa., include elementary pamphlets on Hardening and Tempering, and on Heat Treatment of Low Carbon Steel in their Tool Making, and Blacksmithing and Forging Divisions of the Courses in Shop Practice. They state that these pamphlets are not intended as a complete course on the subject. Correspondence courses are also given by various universities, usually in connection with the work of the Engineering Schools.

Such Engineering Extension courses are or have been given by:

University of Arkansas, Fayetteville, Ark.
University of California, Berkeley, Calif.
University of Chicago, Chicago.
University of Colorado, Boulder, Colo.
University of Florida, Gainesville, Fla.
University of Kansas, Lawrence, Kan.
University of Maine, Orono, Me.
University of Nebraska, Lincoln, Neb.
University of North Dakota, Grand Forks, N. D.
University of Oklahoma, Norman, Okla.
Penn State College, State College, Pa.
Purdue University, Lafayette, Ind.
University of Wisconsin, Madison, Wis.
University of Washington, Seattle, Wash.

Enrollment in courses given by state institutions is not necessarily limited to residents of the state.

Interested parties should correspond with the institutions giving these courses to find out whether the course is now being given and what it covers, since the scope of these courses is subject to change, and metallurgy and heat treatment may be dealt with more or less briefly.

Night Schools

The meetings of the local chapters of the American Society for Steel Treating have a distinct educational value. Besides the usual meetings, some of the chapters, in cooperation with local educational institutions, offer night school courses in heat treating. Such courses are being, or have been, given at the following:

Chapter	Institution
Golden Gate—San Francisco, Calif.	
Los Angeles	University of California
Boston	Massachusetts Institute of Technology
North West	University of Minnesota
Montreal, Canada	McGill University
Detroit	Cass Technical High School and College of the City of Detroit
Cincinnati	University of Cincinnati
Chicago	Lewis Institute
Philadelphia	Temple University
Pittsburgh	Carnegie Institute of Technology
Syracuse	Syracuse, University
Worcester, Mass.	Worcester Polytechnic Institute.
Providence, R. I.	
New Haven	Yale University
Milwaukee	Milwaukee Continuation School

The plans for such courses of the chapter nearest the inquirer can be ascertained at any time from the American Society for Steel Treating, Society headquarters, 7016 Euclid Avenue, Cleveland.

Night courses are given by H. M. Boylston at Cleveland College of Western Reserve University, affiliated with Case School of Applied Science, Cleveland.

APPENDIX D

Selected Bibliography

A few articles of particular interest in connection with the subject matter of this outline are listed below:

General

75. Necessary Precautions to Obtain Uniformity in Heat Treatment of Steel, Loudenbeck, H. C., Transactions, American Society for Steel Treating, Vol. 1, 1921, p. 298.
76. Theory of the Heat Treatment of Steel, Mitchell, W. M., *Forging-Stamping-Heat Treating*, Vol. 8, 1922, pp. 52, 114, 162.

77. Design from the Heat Treating Standpoint, Eaton, G. M., TRANSACTIONS American Society for Steel Treating, Vol. 12, 1927, p. 794, reprint No. 27115, 35 cents.
See also refs. 54 and 55.

Annealing, Normalizing and Spheroidizing

78. Recommended Practice for the Heat Treatment for plain Carbon Steel, *Handbook*, American Society for Steel Treating, Cleveland, $7.50.
79. Recommended Practice for Annealing of Miscellaneous Rolled and Forged Carbon Steel Objects, American Society for Testing Materials, A. S. T. M. Standards, 1927, p. 362, Serial designation A-35-24.
80. Heat Treating Definitions, American Society for Steel Treating Handbook.
81. Agree Upon Heat Treatment Terms, *Iron Age*, July 14, 1927, p. 79.
82. Furnace Atmospheres and Their Relation to the Formation of Scale, McCormick, George C., TRANSACTIONS, American Society for Steel Treating, Vol. 2, 1922, p. 1007.
83. Spheroidized Cementite in Hypoeutectoid Steels, MacPherran, R. S., and Harper, J. F., TRANSACTIONS, American Society for Steel Treating, Vol. 6, 1924, p. 341.
See also ref. 55.

Quenching and Rate of Cooling

84. High Tensile Strengths with Low Carbon Steels, Smith, R. H., *Proceedings*, American Society for Testing Materials, Vol. 24 (2), 1924, p. 618; Some Physical Properties of Low Carbon Steels, TRANSACTIONS, American Society for Steel Treating, Vol. 7, 1925, p. 569.
85. Influence of Temperature, Time and Rate of Cooling on Physical Properties of Carbon Steel, Howe, H. M., Foley, F. B., and Winlock, J., *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 69, 1923, p. 722,—and a further report by Foley, F. B., Clayton, C. Y., and Remmers, W. E., Vol. 73, 1926, p. 929.
86. The Hardening of Steel, Jeffries, Z., and Archer, R. S., TRANSACTIONS, American Society for Steel Treating, Vol. 4, 1923, p. 263.
87. Cooling Properties of Technical Quenching Liquids, Pilling, N. B., and Lynch, T. D., *Transactions*, American Institute of Mining and Metallurgical Engineers, Vol. 62, 1920, p. 665.
88. Initial Temperature and Mass Effects in Quenching, French, H. J., and Klopsch, O. Z., TRANSACTIONS, American Society for Steel Treating, Vol. 9, 1926, p. 33, reprint 2612, 50 cents.

89. Quenching Diagrams for Carbon Steels in Relation to Some Quenching Media for Heat Treatment, French, H. J., and Klopsch, O. Z., TRANSACTIONS, American Society for Steel Treating, Vol. 6, 1924, p. 251.

90. Some Characteristics of Quenching Curves, French, H. J., and Klopsch, O. Z., TRANSACTIONS, American Society for Steel Treating, Vol. 9, 1926, p. 857.

91. Quenching Properties of Glycerine and Its Water Solutions, Scott, Howard, TRANSACTIONS, American Society for Steel Treating, Vol. 6, 1924, p. 13, reprint 2471, 40 cents.

92. The Theory in Quenching Steel, Honda, K., TRANSACTIONS, American Society for Steel Treating, Vol. 4, 1923, p. 450.

93. High Temperature Quenching Treatment Applied to Cold Heading Ball Dies of Plain Carbon Tool Steel, Wright, F. L., Feb., 1928, TRANSACTIONS, American Society for Steel Treating, Vol. 13, p. 282. See also ref. 55.

Tempering

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APPENDIX E

DEFINITIONS

The following tentative definitions of terms relating to heat treatment were prepared by a joint committee representing the American Society for Steel Treating, the American Society for Testing Materials and the Society of Automotive Engineers. They appear in the American Society for Steel Treating HANDBOOK, pp. 71 to 73; in TRANSACTIONS, American Society for Steel Treating, Vol. 12, 1927, p. 328; *Proceedings*, American Society for Testing Materials, Vol. 27, Part I, 1927, p. 703 and elsewhere.

DEFINITIONS

1. *Heat Treatment.*—An operation or combination of operations involving the heating and cooling of a metal or an alloy in the solid state.

   NOTE: This is for the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working are excluded from the meaning of this definition.

2. *Quenching.*—Immersing to cool.

   NOTE: Immersion may be in liquids, gases or solids.

3. *Hardening.*—Heating and quenching certain iron-base alloys from a temperature either within or above the critical temperature range.
4. *Annealing.*—Annealing is a heating and cooling operation of a material in the solid state.

   NOTE 1.—Annealing usually implies a relatively slow cooling.
   NOTE 2.—Annealing is a comprehensive term. The purpose of such a heat treatment may be:
   (a) To remove stresses.
   (b) To induce softness.
   (c) To alter ductility, toughness, electrical, magnetic or other physical properties.
   (d) To refine the crystalline structure.
   (e) To remove gases.

In annealing the temperature of the operation and the rate of cooling depend upon the material being heat treated and the *purpose* of the treatment.

Certain specific heat treatments coming under the comprehensive term "annealing" are:

A. Normalizing.—Heating iron-base alloys above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

NOTE: In the case of hypereutectoid steel, it is often desirable to heat above the Ac_{cm} line, as shown in Fig. 2.

B. Spheroidizing.—Prolonged heating of iron-base alloys at a temperature in the neighborhood of, but generally slightly below, the critical temperature range, usually followed by relatively slow cooling.

NOTE 1.—In the case of small objects of high carbon steels, the spheroidizing result is achieved more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range.
NOTE 2.—Tempering, meaning the operation of hardening followed by reheating, of the carbide.

C. Tempering (also termed Drawing).—Reheating, after hardening to some temperature below the critical temperature range followed by any rate of cooling.

NOTE 1.—Although the terms "tempering" and "drawing" are practically synonymous as used in commercial practice, the term "tempering" is preferred.
NOTE 2.—Tempering meaning the operation of hardening followed by reheating, is a usage which is illogical and confusing in the present state of the art of heat treating and should be discouraged.

D. Malleableizing.—Malleableizing is a type of annealing operation with slow cooling whereby combined carbon in white cast iron is transformed to temper carbon and in some cases the carbon is entirely removed from the iron.

NOTE.—Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

E. Graphitizing.—Graphitizing is a type of annealing of cast iron whereby some or all of the combined carbon is transformed to free or unconbined carbon.

5. *Carburizing (Cementation).*—Adding carbon to iron-base alloys by heating the metal below its melting point in contact with carbonaceous material.

NOTE.—The term "carbonizing" used in this sense is undesirable and its use should be discouraged.

6. *Case Hardening.*—Carburizing and subsequent hardening by suitable heat treatment, all or part of the surface portions of a piece of iron-base alloy.

Case.—That portion of a carburized iron-base alloy article in which the carbon content has been substantially increased.

Core.—That portion of a carburized iron-base alloy article in which the carbon content has not been substantially increased.

NOTE.—The terms "case" and "core" refer to both case hardening and carburizing.

7. *Cyaniding.*—Surface hardening of an iron-base alloy article or portion of it by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

In Erratum: Attention is directed to a printer's error which occurred in Part II of this article as published in November TRANSACTIONS. The last line of page 745 should have been the first line of that page.

HEATING HIGH SPEED STEEL TO 2400 DEGREES FAHR. IN MOLTEN LEAD

By Wilbur C. Searle

Abstract

This paper describes the apparatus and method of heating high speed steel to 2300 to 2400 degrees Fahr. in molten lead. Photomicrographs show the structure obtained in specimens at 2200, 2300 and 2400 degrees Fahr.

Introduction

THE use of a lead bath as a means of heating high speed steel for hardening is not new. It has been used for a number of years by at least two concerns in Worcester. The following paper is the first so far as we know to describe the process.

Character of Work—The work being hardened includes small and large pieces, any pieces that will go into the crucible can be hardened. Flat cutters, circular formed cutters, reamers, etc., are all hardened successfully by this method. It is possible to harden part of a flat cutter and have part not hard, also the cutting portion of a reamer can be hardened and the shank left soft.

Heating

Preheat—The preheating is done usually in an electric oven furnace equipped with an automatic control. The control is set for 1600 degrees Fahr.

High Heat—A gas furnace is used for heating the lead which is contained in a graphite crucible. The furnace is 22 inches outside diameter. The heating chamber is 12½ inches in diameter by 11 inches deep and is heated by four burners, two on each side coming in on a tangent. The crucible is 9 inches in diameter by 11 inches high outside dimensions and sets on three carborundum bricks about 1½ inches above the bottom of the heating chamber.

A paper presented before the tenth annual convention of the society, held in Philadelphia, October 8 to 12, 1928. The author, W. C. Searle, a member of the society, is associated with the Leland-Gifford Co., Worcester, Mass. Manuscript received June 22, 1928.

The bottom of the chamber slopes to an outlet to carry off the lead if a crucible should break.

The lead is ordinary commercial lead. It is removed from the crucible at the end of each heat and poured into molds. At the beginning of the heat the lead blocks are placed in the crucible and added to as the lead melts until the desired quantity is in the crucible. It is then covered with a two-inch layer of ground bone to prevent vaporization.

The temperatures are measured by a base metal couple (iron-chromel) and an indicating pyrometer. The readings are checked by comparison with another pyrometer up to 1600 degrees Fahr. and by means of cones at 1958 degrees Fahr. The fire-end of the pyrometer is enclosed in a ½-inch iron pipe with welded end. This, in turn, is inserted in a graphite protection tube 1¾ inches in diameter. This is placed in the molten bath and allowed to remain during the heat.

The gas is ordinary city gas of 530 B. t. u. per cubic foot. Air at about one pound pressure is used, the mixing taking place at the burners. The time to bring the bath up to 2300 to 2350 degrees Fahr. is 2½ to 3 hours. 900 cubic feet of gas are used and about 200 cubic feet per hour thereafter.

Method of Operation

The pieces are taken from the preheating furnace one at a time in a pair of tongs and held in the molten lead for a definite number of seconds depending on the size of the piece. The ends of the tongs are just above the lead surface. The piece is removed at the end of the immersion period and dropped into a basket in the quenching oil. At the end of the heat the pieces are removed from the quench, washed in hot washing compound and placed in the electric furnace for tempering at 1050 to 1100 degrees Fahr.

Structure

The photomicrographs show the structure obtained at 2200, 2300 and 2400 degrees Fahr. The sample heated to 2400 degrees Fahr. shows the beginning of fusion along the grain boundaries. The samples from which the pictures were made were ½ inch in diameter by 4 inches long and were immersed in the bath for 50 seconds.

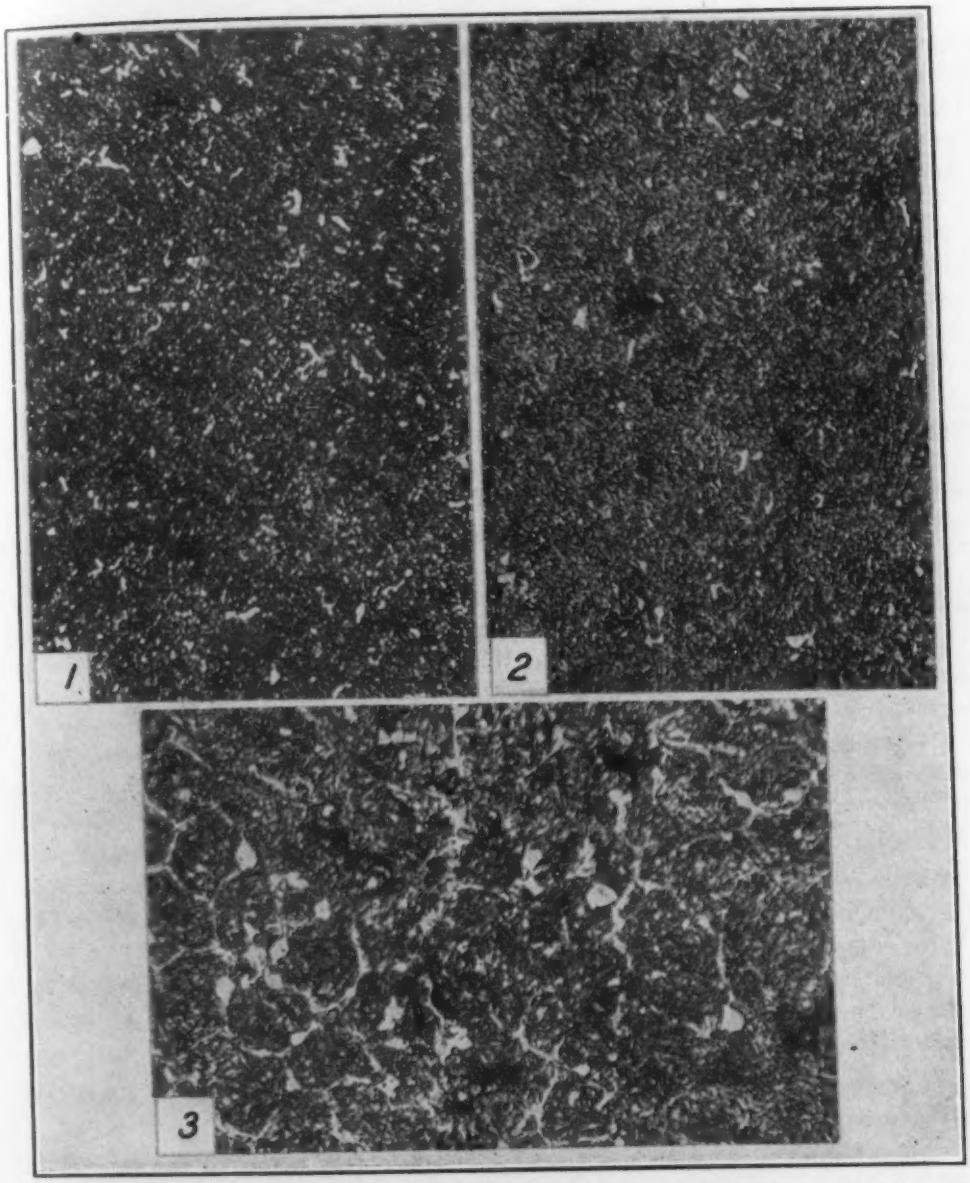

Fig. 1—Photomicrograph of High Speed Steel, Heated in Lead Bath to 2200 Degrees Fahr. Quenched in Oil, Tempered at 1100 Degrees Fahr. × 500.

Fig. 2—Photomicrograph of High Speed Steel Heated in Lead Bath to 2300 Degrees Fahr. Tempered at 1100 Degrees Fahr. × 500.

Fig. 3—Photomicrograph of High Speed Steel Heated in Lead Bath to 2400 Degrees Fahr. Quenched in Oil, Tempered at 1100 Degrees Fahr. × 500.

Conclusion

This method of high speed steel hardening is simple and very satisfactory for moderate production. There is very little danger of destroying delicate edges before the tool is heated through.

ACKNOWLEDGMENT

Acknowledgment should be made to the Leland-Gifford Co. for permission to use and describe equipment; to Crompton and Knowles Co. for photomicrographs and to other members of the Worcester Chapter A. S. S. T. for advice and helpful criticism.

DISCUSSION

Written Discussion: By M. H. Frommann, Chief Chemist, Reed and Prince Mfg. Co., Worcester, Mass.

Mr. Searles is to be congratulated for bringing out this paper on a subject that most authors tell us cannot be done or advise against. They give various reasons such as, the lead oxidizes too rapidly, high volatilization with attendant fumes which are offensive and poisonous, inability of pots to stand up, etc.

Heating molten lead to high speed steel hardening heat has many advantages over other liquid baths.

1. The high heat conductivity of lead.
2. Its low specific heat. This causes a greater drop in temperature when cold work is introduced, but this is offset by the advantage that a cold pot can be brought up to heat more quickly and with less fuel.
3. Low latent heat of fusion.
4. No affinity for water.
5. The life of the pots is four to five times longer than with any other liquid steel treating bath at high speed heat.

High speed lead baths have their disadvantages, and the chief one in my experience has been the tendency of the lead to stick to the work, especially in the fine threads of tools such as chasers, taps, etc. I have seen lead in threads that could not be removed by the ordinary method of brushing or picking and had to be reheated to high speed heat in another medium before the threads were clean. This tendency of the lead to stick in threads sometimes materially affects the uniformity of cooling.

Written Discussion: By S. C. Spalding, Metallurgist, Halcomb Steel Co., Syracuse, N. Y.

The hardening of high speed steel is always a very pertinent subject. Both the manufacturers of and the users of high speed steel welcome any contribution to the subject. Tools made of high speed steel are usually relatively expensive and any method to make their treatment more uniform and safe is to be desired. Lead hardening of carbon steels is used because it promotes uniformity. It is adapted to mass production by less skilled operators, there is no scaling and it lends itself to local or selective hardening as portions only can be heated for hardening while other portions of the same part may be left soft. Its disadvantages are, less flexibility as due to the mass of the lead, temperatures can be changed but slowly, it is a very rapid heating medium and unless great skill and care are exercised it will become contaminated or dirty and cause decarburization and soft spots.

Considering the process described by the author of the paper, it would seem that the same advantages and disadvantages as applied to carbon steel hardening would also apply to high speed hardening. I would think that there might be even more risk of decarburization from the lead when operating at such high temperatures also due to the fact that the pieces when taken from the preheating furnace and introduced into the lead would be coated with an appreciable amount of iron oxide scale. Another difficulty which, though encountered in carbon steel hardening, is not so serious, due to the low temperatures, is pot life. At high speed hardening temperatures of 2350 to 2400 degrees Fahr. we would think it would be very difficult to maintain pots without frequent burning out. Due to this tendency there exists the inclination by the operator to keep the temperatures down to 2200 to 2250 degrees Fahr. which will result in unsatisfactory hardening of the steel.

In conclusion, we wish to congratulate Mr. Searles on bringing out some new and interesting ideas on high speed hardening and we wish it understood that the questions expressed here are not so much in the spirit of criticism as to state some of the questions which have come to our mind in reading the paper.

Written Discussion: By A. H. Kingsbury, Metallurgist, Atha Works, Crucible Steel Company of America.

While I have not had any experience in heating high speed steel in lead, it is quite apparent that the process is practicable and undoubtedly produces satisfactory results if controlled in the manner described by the author.

In examining the photomicrographs, it is noted that they represent structures of the hardened steel which have been tempered to 1100 degrees Fahr. In the absence of definite information as to the length of time and the etching reagent used, it is difficult for one who has been examining hardened high speed steel structures to draw any definite conclusions from these photos as to the effect of the treatment on structure, and make comparisons between the lead heating process and those being generally used at the present time.

A NEW METHOD OF NITROGEN CASE HARDENING

By G. F. Bason

Abstract

This paper reports an investigation of the hardening of collector rings on electrical machinery. It is believed that this hardening may be due to the ring being bombarded with nitrogen ions thereby nitrogenizing the surface of the steel. It is suggested that this process be more or less closely imitated as a possible means of evolving a practical method of nitriding superior to the present ones.

IN the course of the past summer's employment with some builders of electrical machinery, the writer was given the problem of investigating some rather annoying trouble that these manufacturers had been experiencing with collector rings. The trouble, as described by the service department, was as follows:

(1) After service of various degrees of duration under operating conditions, the rings became hardened in spots and these spots caused sparking and pitting of the rings. The spots appeared to be glass hard and seemed by their shape and by the spacing between them to have been transmitted to the rings from the brushes when the former were at standstill. When there were two brushes to a ring (and there were generally at least two) there were two spots found to have developed. The shape of the hardened spot was always identical with the shape of the brush contact surface, and the distance between the spots was always the same as that between the brushes.

(2) In some cases, several ring replacements had been made in succession, and with each replacement the trouble appeared again on the new ring, the polarity of which was the same as the one replaced.

(3) Machines having no perceptible vibration as well as those that had, were affected.

(4) Machines with direct-connected exciters and those with separately driven exciters were also alike susceptible.

The author, G. F. Bason is assistant professor of electrical engineering, Cornell University, Ithaca, New York. Manuscript received October 5, 1928.

(5) High speed steel rings gave the greatest trouble. Next in order were iron rings; and bronze rings gave the least.

In looking for the cause of this trouble, the writer was forced, as follows, to the conclusion that the rings had been nitrogen case hardened:—

(1) Vibration, as a cause, is eliminated by part (3) of the service department's report.

(2) Part (4) eliminates the possibility that a heavy flow of current through the rings at standstill produced a pitting that looked like hardening. For when a machine with a direct connected exciter is shut down, the exciting current that is handled by the rings is zero when the machines come to standstill; and part (1) shows that the spotting was produced at standstill.

(3) The occurrence of the trouble on one ring repeatedly pointed to some sort of electrolytic action or ionization as a contributing cause, since the connections were never changed to reverse the current.

(4) That ionization does occur in the air film of the brush contact is evidenced by the fact that the resistance characteristic of a brush contact is like that of an arc.

The evidence thus pointed to some chemical or metallurgical reaction between the hot brushes and rings, at standstill, following a preparatory electrolytic or ionizing action while the machines were running.

With this in mind, the writer was fortunate enough to obtain the counsel of a prominent metallurgist, and on presenting the above evidence to him, was told that he might look to nitration as a possible cause, since effects produced by electronic action are produced much faster and at considerably lower temperatures than the same effects produced by molecular action alone. He considered carburization rather unlikely.

Research into the limited literature on the subject disclosed the following facts about the Fry method of nitration:

(1) To obtain a Brinell hardness of about 950 at the surface, the steel must be kept at 950 degrees Fahr. for 90 hours, (except for small work) but nitrogen begins to diffuse into the metal as low as 500 degrees Fahr.

(2) No subsequent heating and quenching is required.

(3) Special steel must be used for good results, but in mild steel (the material used in the collector rings that gave the most

trouble) the penetration is rapid, and needles of ferrous or ferric nitride form, rendering the surface exceedingly brittle.

The evidence seems conclusive to the writer, but others will ask how it happens. One possibility is as follows:

While performing its function, one of the revolving rings is continually being bombarded with nitrogen ions; but the heat generated in the air film of the contact is rapidly carried away, and, furthermore, while some hardening results, it is uniformly distributed around the ring. When the ring comes to rest, the area under the brush retains its heat longer than does the remainder of the ring, because carbon (the brush material) has a lower coefficient of heat conductivity than does iron or steel, so that most of the heat under the brush has to flow from that spot to the exposed portions of the rings.

Thus, when on occasion the ring temperature happens to be at the critical value at this spot, the above mentioned nitride needles form, rendering this spot a poor conductor, and from then on sparking produces the visible pitting observed.

The thought at once suggests itself that by finding means for duplicating and controlling the process evidenced by the formation of these spots, engineers would evolve a method of nitration superior to the Fry method because it would be faster.

The first means to be thought of would imitate more or less closely the process by which collector rings are accidentally hardened by setting up an electric circuit composed of the steel as one electrode and a granular conductor surrounding the portion to be hardened, as the other electrode, and setting up an electron flow from the granular electrode to the steel.

By properly proportioning the volumes of steel and negative electrode, the proper heat and amount of nitrogen bombardment could be maintained.

A still closer imitation of the conditions investigated might be more effective. Such an imitation might consist of means for producing such a motion of the piece to be hardened as will move the surfaces, upon which the hardening is desired, past electrodes which are bearing upon or close to these surfaces, means for providing an electron flow, through an air or nitrogen atmosphere, from the electrodes to the surfaces, and means for maintaining the surfaces at any required temperature.

TENTATIVE RECOMMENDED PRACTICE FOR THE HEAT TREATMENT OF ALLOY STEEL CASTINGS*

General—This recommended practice covers the process to be followed for the heat treatment of alloy steel castings and applies generally to commercial alloys castings for ordinary construction purposes and not for special use.

Chemical Composition—The chemical compositions of the steel considered in this recommended practice are given in Table I.

Cooling and Cleaning of Castings

Alloy castings should be cooled in the molds to a temperature below the critical range, but as the brittleness increases with the decrease of temperature they should be shaken out preferably as soon as they become black and cleaned while they are still warm.

Cleaning should be performed rapidly so that the castings can be placed in the annealing furnace while still as hot as possible, but the cleaning must be sufficient to insure a thorough and complete penetration of heat during the heat treating operations.

Before heat treating, flame cutting of gates and risers is somewhat dangerous unless the castings are hot. If the risers or gates are broken instead of cut, the operation should be performed while the castings are warm, otherwise stresses are set up and minute cracks are developed which show up in the quenching operation. When castings are placed in the furnace, the temperature of the latter should preferably be the same as the castings.

Heat Treatments of Alloy Castings

Heat treatments may be classified as follows:

Normalizing
Annealing
Quenching
Tempering

The heat treatments to be used depend upon the chemical composition of the castings and the physical properties desired. Quenching and tempering treatments develop maximum properties. Intermediate properties may be secured by normalizing and tempering. Full annealing produces only a nominal increase in physical properties, not consistent with the cost of the alloys.

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*This is a Tentative Recommended Practice and will remain tentative for at least one year, until adopted by the Board of Directors and the Recommended Practice Committee of the A. S. S. T. This practice is not intended for a specification and should not be interpreted as such.

The membership of the Sub-committee on the Heat Treatment of Steel Castings is as follows:

A. N. Conarroe, chairman
A. W. Lorenz
Fred Grotts
A. T. Baumer
A. M. Johnson
Dr. A. E. White
L. W. Spring

Criticisms of this tentative practice are solicited and should be directed to J. E. Donnellan, Secretary of the committee, 7016 Euclid Ave., Cleveland.

Table I
Approximate Chemical Compositions*

Steel No.	Type of Steel	C	Mn	Si	Cr	Ni	Mo	V
1	C-V	0.25–0.35	0.60–0.90	0.20–0.50[1]	.....	.....	.....	0.15–0.20
2		0.35–0.35	0.60–0.90	0.20–0.50	.....	.....	.....	0.15–0.20
3		0.45–0.55	0.60–0.90	0.20–0.50	.....	.....	.....	0.15–0.20
4	C-Cr	0.25–0.35	0.60–0.90	0.20–0.60	0.80–1.10	.....	.....	.....
5		0.35–0.45	0.60–0.90	0.20–0.60	0.80–1.10	.....	.....	.....
6		0.45–0.55	0.60–0.90	0.20–0.60	0.80–1.10	.....	.....	.....
7	Cr-V	0.25–0.35	0.60–0.90	0.20–0.60	0.80–1.10	.....	.....	0.15–0.20
8		0.35–0.45	0.60–0.90	0.20–0.60	0.80–1.10	.....	.....	0.15–0.20
9		0.45–0.55	0.60–0.90	0.20–0.60	0.80–1.10	.....	.....	0.15–0.20
10	Cr-Ni	0.25–0.35	0.60–0.90	0.20–0.60	0.50–0.90	1.25–1.75	.....	.....
11		0.35–0.45	0.60–0.90	0.20–0.60	0.50–0.90	1.25–1.75	.....	.....
12		0.45–0.55	0.60–0.90	0.20–0.60	0.50–0.90	1.25–1.75	.....	.....
13	Cr-Mo	0.25–0.35	0.60–0.90	0.20–0.60	0.70–1.00	.....	0.25–0.35	.....
14		0.35–0.45	0.60–0.90	0.20–0.60	0.70–1.00	.....	0.25–0.35	.....
15		0.45–0.55	0.60–0.90	0.20–0.60	0.70–1.00	.....	0.25–0.35	.....
16	Mn	0.25–0.35	1.00–1.50	0.20–0.50	.....	.....	.....	.....
17		0.25–0.35	1.50–1.75	0.20–0.50	.....	.....	.....	.....
18		0.35–0.45	1.00–1.50	0.20–0.50	.....	.....	.....	.....
19		0.35–0.45	1.50–1.75	0.20–0.50	.....	.....	.....	.....

*Maximum sulphur: 0.060 per cent. Maximum Phosphorus: 0.050 per cent.
[1]0.20 to 0.30 per cent silicon preferred.

In general, it should be employed only to increase the machinability of the steel, or for other special purposes.

Normalizing

The purpose of normalizing is to relieve cooling strains, refine the cast structure and to produce as high physical properties as are possible without liquid quenching. To accomplish this purpose, castings are placed in the furnace, preferably while they are still warm, as noted above, and heated slowly and uniformly to the normalizing temperatures as given in Table II, after which they should be allowed to cool uniformly and as rapidly as possible in still air. (Air blast is not usually considered acceptable.)

Castings should be held at temperatures approximately one hour for each inch of thickest cross section. Manganese steels, numbers 16 to 19, require a longer period of heating.

After normalizing the castings should be further heat treated by tempering, or by quenching and tempering as described later in this practice.

Full Annealing

Although full annealing of alloy steel castings is not generally recommended, it is sometimes necessary where machinability is desired, but the castings if full annealed should be further heat treated after machining to bring out the available physical qualities.

Table II
Normali ing Treatments

Steel Nos.	Temperature Degrees Fahr.	Cool in
1, 2, 3, 16, 17, 18, 19	1600-1700	Air
4 to 15	1600-1800	Air

When the castings have had no preliminary treatment, they may be full annealed at the normalizing temperatures as given in Table II, followed by furnace cooling.

If the steel has been previously normalized it may be annealed at lower temperatures as given in Table III, holding at temperature a sufficient time

Table III
Annealing Temperatures for Alloy Castings

Steel Nos. as listed in Table I	Temperature Degrees Fahr.	Cool in
1, 2, 3, 16, 17, 18, 19	1500-1600	Furnace
4 to 15	1550-1650	Furnace

to insure thorough soaking, the rate of cooling being regulated to give the desired machining qualities.

Quenching

Quenching should be employed where maximum physical properties are necessary.

After properly normalizing or annealing the castings should be heated slowly and uniformly to the quenching temperature as given in Table IV. They should be held at temperature for at least 30 minutes per inch of section before quenching.

When water is used as the quenching medium, the temperature of the water should preferably be maintained at 125 to 150 degrees Fahr., especially for the higher carbon contents.

When the size and design of the castings are such that quenching might cause cracking if kept in the water or oil until cold, the castings should be removed from the quenching bath while still hot enough to dry the water quickly or in case of oil, the castings should be hot enough to cause the oil to smoke freely on the surface of the castings.

Tempering

As soon as possible after normalizing or quenching, castings should receive a tempering treatment. The temperature of the furnace receiving the charge should be approximately the same as that of the castings.

The purpose of tempering is to relieve the strains and brittleness caused by quenching or normalizing and to moderate the hardness, i. e., to toughen the material. The temperature to be used depends upon the hardness and

Table IV
Quenching and Tempering Temperature for Alloy Castings

Steel Nos. as listed in Table I	Type of Steel	Quenching Temperatures	Quenching Medium[1]	Maximum Tempering Temp. Deg. Fahr.	Cool in
1	C-V	1550-1600	Water or Oil	1300	Air or Furnace
2		1500-1550	Water or Oil	1300	Air or Furnace
3		1475-1500	Water or Oil	1300	Furnace
4	C-Cr	1575-1650	Water or Oil	1275	Air or Furnace
5		1525-1575	Water or Oil	1275	Air or Furnace
6		1500-1525	Water or Oil	1275	Furnace
7	Cr-V	1575-1650	Water or Oil	1275	Air or Furance
8		1525-1575	Water or Oil	1275	Air or Furnace
9		1500-1525	Water or Oil	1275	Furnace
10	Cr-Ni	1515-1550	Water or Oil	1250	Air or Furnace[2]
11		1490-1515	Water or Oil	1250	Air or Furnace[2]
12		1475-1490	Water or Oil	1250	Furnace[2]
13	Cr-Mo	1575-1650	Water	1300	Air or Furnace[3]
14		1525-1575	Oil	1300	Air or Furnace[3]
15		1500-1525	Oil	1300	Furnace[3]
16	Mn	1600-1650	Water	1250	Air or Furnace
17		1600-1650	Water	1250	Air or Furnace
18		1550-1600	Water	1250	Air or Furnace
19		1550-1600	Water	1250	Air or Furnace

[1]Air quenching is often made use of in the hardening of alloy steel castings of intricate design which would be likely to crack in the more drastic water or oil quench.
[2]The shock resistance is sometimes improved by oil quenching from the tempering temperature.
[3]A long soak is required at the tempering temperature.

physical properties desired. Usually the higher the tempering temperature, up to the critical range, the softer and more ductile the steel. For maximum hardness and strength, a tempering temperature only sufficient to relieve strains is used. The maximum tempering temperatures recommended are given in Table IV.

Tempering is more nearly a function of temperature than time, and except in special cases, the time the material is held at the tempering temperature is just sufficient to insure a complete equalization of the heat throughout the heaviest section.

Uses

Carbon-vanadium castings are generally used where toughness is the governing factor, such as for locomotive frames, gear blanks, and castings subjected to sudden shocks.

Carbon-chromium castings have a special application for wearing parts where toughness is not essential, for example: dies, stamps, and crusher jaws.

The other steels listed possess desirable combinations of hardness, strength, and toughness not obtainable with carbon cast steel. These castings are used for such articles as heavy duty gears and pinions, car wheels, shovel teeth, racks, chain, valves and fittings, caterpillar treads, etc.

Due to their higher physical properties it is possible to obtain greater strength for a given cross section than with carbon steel castings. These

alloys, therefore, find particular application where reduction of weight is important, and where high stresses are encountered.

Notes About the Process

Castings should be charged into the furnace in such a manner that lighter castings will be protected from the heat of the furnace by the heavier castings. Should the castings be of similar section, care must be exercised so as not to overheat those on the outside of the charge before the inner ones have reached the annealing temperature.

When charging the furnace, the castings should be piled loosely so that the hot gases will have free circulation throughout the charge. To further insure free circulation of the gases, it is advisable to pile the castings loosely on the perforated racks or other suitable fixtures which elevate the castings a few inches above the floor of the furnace and so permit free circulation of the hot gases. When cooling from the normalizing temperature, this practice of piling the castings on racks also insures free circulation of the air, promoting more rapid and uniform cooling.

Sufficient number of thermocouples should be used and so arranged in the furnace and if possible in the charge of castings that the desired temperature can be maintained at the top, center, bottom and sides of the charge.

Steel castings should be grouped for heat treatment so that the carbon content of the entire charge falls within one of the carbon ranges given in the recommended practice. Castings of intricate design, or where a heavy and light section are adjacent, should not be quenched, however, when necessary, utmost care should be exercised.

Alloy steel castings, in most cases, will harden appreciably if heated above the critical range and allowed to cool in the air, therefore, they should always be tempered after normalizing.

When the enumerated methods of annealing are not satisfactory, alloy castings may sometimes be appreciably softened by heating within the critical range and holding for a considerable length of time.

The physical properties obtained by heat treating alloy castings are destroyed by the local application of heat such as in welding or straightening. These operations produce dangerous local disturbances of grain structure, hardness, and excessive strains. Castings should, therefore, be retreated after such practice.

The rate of cooling in the normalizing practice is merely relative depending upon the size of the furnace and the size of charge. The smaller the load, the more drastic the cooling, and, therefore, the higher the physical strength and the lower the ductility.

It is commercial practice to use test specimens cut from a separately cast block or from test coupons attached to the casting as a basis for determining the physical properties of the castings. Test pieces or test coupons should be heat treated with the castings which they represent.

THE ENGINEERING INDEX

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Arrangements have been made with The American Society of Mechanical Engineers whereby the American Society for Steel Treating will be furnished each week with a specially prepared section of The Engineering Index Service. It is to include items descriptive of articles appearing in the current issues of the world's engineering and scientific press of particular interest to members of the American Society for Steel Treating. These items will be selected from the Weekly Card Index Service of the Index published by the A. S. M. E.

In the preparation of the Index by the staff of the A. S. M. E. some 1,700 domestic and foreign technical publications received by the Engineering Societies Library (New York) are regularly searched for articles giving the results of the world's most recent engineering and scientific research, thought, and experience. From this wealth of material the A. S. S. T. will be supplied with a selective index to those articles which deal particularly with steel treating and related subjects.

Photostatic copies (white printing on a black background) of any of the articles listed may be secured through the A. S. S. T. The price of each print, up to 11 by 14 inches in size, is 25 cents. Remittances should accompany orders. A separate print is required for each page of the larger periodicals, but whenever possible two pages will be photographed together on the same print. When ordering prints, identify the article by quoting from the Index item: (1) Title of article; (2) name of periodical in which it appeared; (3) volume, number, and date of publication of periodical; and (4) page numbers.

AIRPLANES

MANUFACTURE (WESTLAND). Notable Establishments. *Machy. Market (Lond.)*, no. 1441, June 15, 1928, pp. 545-548, 13 figs.

Description of Westland works of Petters, Ltd. and their methods of manufacturing oil engines and aircraft; types and sizes of Petter oil engines; line production; erection methods; power house which provides electric power to whole works; production of Widgeon and Wapiti airplanes with details of planes themselves.

METAL. Uses of Metal Grow in Canadian Aeroplane Plant. *Can. Machy. (Toronto)*, vol. 39, no. 13, June 28, 1928, pp. 87-88, 2 figs.

Designers are turning more and more towards metal construction; metal construction, however, offers many difficulties; large use of dies; rust prevention; ordinary acid-bath methods of rust prevention quite unsuitable for airplane manufacture; metal construction calls for welded joints.

ALLOYS

EUTECTIC. Work-Softening of Eutectic Alloys, F. Hargreaves and R. J. Hills. *Inst. of Metals—Advance Paper (Lond.)*, no. 474, for mtg. Sept. 4-7, 1928, 14 pp., 11 figs.

Previous work is reviewed, and micrographic changes which take place on working and annealing lead-tin eutectic are described; results of ball-hardness tests on other lead-tin alloys and with those on sample of worked recrystallized eutectic alloy; density determinations; experiments on cadmium-zinc eutectic; mechanism of working and of annealing is discussed and partial theory offered; softening is due to presence of two phases and is not peculiarly of eutectic structure. Bibliography.

HEAT RESISTING. Heat-Resisting Alloys, T. H. Turner. *Am. Metal Market*, vol. 35, no. 155, Aug. 14, 1928, pp. 17-20, and 22-23.

Considerations of alloys used for specific industrial purposes such as in steam engineering furnace work, electric machinery, internal-combustion engines, guns and rifles, hot forging dies and chemical engineering.

REACTIVE. Methods for the Thermal and Microscopic Investigation of Alloys of Reactive Metals, W. Hume-Rothery. *Inst. of Metals—Advance Paper (Lond.)*, no. 478, for mtg., Sept. 4-7, 1928, 16 pp., 9 figs.

Methods suitable for thermal and microscopical investigations are described and criticized; discusses justification for method, introduced by early German workers, in which composition of phase is deduced from duration of arrests on cooling curves; method is sound, but in case of peritectic reactions, or where solid solutions are present, it is unsound at all except very high temperatures.

ALLOY STEEL CASTINGS

General Characteristics of Alloy Steel Castings. J. W. Frank. *Am. Metal Market*, vol. 35, no. 155, Aug. 14, 1928, pp. 14-16.

Paper presented before Am. Foundrymen's Assn., previously indexed.

ALUMINUM

METALLURGY. Metallurgy of Aluminum (Lo stato attuale della metallurgia dell' alluminio), V. Ferreri. *Ingegneri (Milan, Italy)*, vol. 11, no. 2, Feb. 1928, pp. 76-81, 2 figs.

General survey of present state of aluminum industry, consisting of summarized account of various methods of extraction and purification and indication of lines along which progress is being made.

Those members who are making a practice of clipping items for filing in their own filing system may obtain extra copies of the Engineering Index pages gratis by addressing their request to the society headquarters, whereby their names will be placed on a mailing list to receive extra copies regularly.

SHEET—PROPERTIES. Aluminum Sheet Grades and Tempers, R. J. Anderson. *Am. Metal Market*, vol. 35, no. 155, Aug. 14, 1928, pp. 3-9, 4 figs.

Principal products of aluminum-sheet rolling mills; how industrial requirements are met by various tempers; mechanical properties as tensile strength, elongation, hardness, bending and cupping tests; commercial sizes, grades, and tolerances; applications of different grades and tempers.

ALUMINUM ALLOYS

Lightness and Strength Combined in New Aluminum Alloy. *Automotive Industries*, vol. 59, no. 8, Aug. 25, 1928, pp. 266-267.

"Hyb-lum" marketed by Sheet Aluminum Corp., Jackson, Mich., as non-tarnishing and non-corrodible and is stable after heat treatment even at elevated temperatures; supplied in four grades; physical properties of each grade are given.

Aluminum Alloys, Z Jeffries. *Mech. Eng.*, vol. 50, no. 9, Sept. 1928, pp. 684-686, 2 figs.

Notes on pure aluminum; aluminum casting alloys; aluminum silicon alloys; improvement of mechanical properties by heat treatment; die-cast and permanent-mold alloys; strong aluminum alloys and their applications. Abstract of address read before meeting of Cleveland section of Am. Soc. Mech. Engrs.

New Aluminum Alloy. *Brass World*, vol. 24, no. 8, Aug. 1928, pp. 251-252.

Sheet Aluminum Corp. of Jackson, Mich., has recently placed on market aluminum alloy said to be fundamentally new in composition and in application to wide variety of products, for many of which aluminum has never before been practicable; it is claimed that it combines lightness and strength to greater degree than any other workable product of its kind ever developed on commercial basis; known by registered name of Hyb-Lum, and protected under U. S. Patent No. 1,579,481.

CHLORINE TREATMENT. Note on the Treatment of Aluminium and Aluminium Alloys With Chlorine, D. R. Tullis. *Inst. of Metals—Advance Paper (Lond.)*, no. 480, for mtg. Sept. 4-7, 1928, 8 pp.

Most aluminum alloys contain dissolved gases; methods for their removal are described as follows: slow solidification, inert-gas, and active-gas methods; experiments are described in which chlorine gas is used as means of remixing dissolved gases; theory is advanced to account for presence of gases in metals; effects of chlorine gas on alloys which are known to extrude metal while cooling, and alloys which are known to disintegrate after long or short periods of storage.

FITS. How Temperature Affects Fits in Aluminum Alloys. *Am. Mach.*, vol. 69, no. 8, Aug. 23, 1928, p. 311.

Builders of automobile engines have experienced difficulty with fit of rods on crankpins in extremes of temperature; customary to allow little more rod clearance in winter than in summer; additional clearance of 0.0004 in. is allowed for new engines that go into service in winter months; experiments with steel reinforced and alloy caps; Franklin and Hupp practice.

RESEARCH. Contribution to Study of Dissolution of Aluminum and its Alloys in Acids (Contribution à l'étude de la dissolution de l'aluminium et de ses alliages dans les acides), X. Waché. *Revue de Métallurgie (Paris)*, vol. 25, no. 6, June 1928, pp. 331-346, 13 figs.

Dissolution of aluminum in hydrochloric acid; influence of rapidity of solidification of aluminum on speed of dissolution; influence of annealing; rolled aluminum; cast aluminum; speed of dissolution after hammering.

STRUCTURE. The Constitution of the Alloys of Aluminum with Copper, Silicon, and Iron, A. G. C. Gwyer, H. W. L. Phillips, and L. Mann. *Inst. of Metals—Advance Paper (Lond.)*, no. 468, for mtg. Sept. 4-7, 1928, 52 pp., 49 figs.

After brief summary of recent work on binary alloys of aluminum with copper, silicon, and iron, constitution and structure of part of ternary systems aluminum-copper-silicon and aluminum-copper-iron are considered; structure and constitution of certain of quaternary alloys of aluminum with copper, iron, and silicon are also considered; deals exclusively with metastable conditions.

TESTING. Fatigue of Castings of Light Aluminum Alloys Subjected to Repeatedly Reversed Stresses, S. S. Nekryty and I. I. Bokov. *Vestnik Inginieurov (Moscow)*, nos. 5 and 6, May and June 1928, pp. 245-251 and 283-289, 17 figs.

Report on elaborate series of static and dynamic tension and compression tests of copper-aluminum alloys, made at Kiev Institute of Technology to establish existence of fatigue or endurance limit for such alloys; description of special apparatus and methods designed in Russion; found Sankey and Strohmeyer methods inapplicable.

WELDING. Spot Welding of Aluminum and Its Alloys, W. M. Dunlap. *Aviation*, vol. 25, no. 9, Aug. 25, 1928, pp. 590-591 and 618-626, 10 figs.

Recommendations for spot welding as developed in laboratories of Aluminum Co. of America; machines with automatic timers best; size and shape of electrode tip important; copper tips chromium plated; setting up machine; strength of joints depends on number of spots; range of thickness that can be pot welded varies with capacity of machine.

ALUMINUM ALLOY CASTINGS

Aluminum Alloys and Casting. *Automobile Engr. (Lond.)*, vol. 18, no. 244, Aug. 1928, pp. 287-288.

Characteristics of modern alloys, with notes on present British practice; selecting casting process; applications and foundry properties of aluminum alloys; treatment to which alloy L24 castings are subjected before use; modified silicon-aluminum alloys gaining favor both in America and England; factors causing pinholes; use of remelt scrap in ingot form very risky.

HIGH TEMPERATURE EFFECTS. Mechanical Properties of Aluminum Casting Alloys at Elevated Temperatures, R. L. Templin, C. Graglio and K. Marsh. *Iron and Steel (A.S.M.E. Trans.)*, vol. 50, no. 16, May-Aug. 1928, pp. 25-36 and (discussion) 36-37, 28 figs.

Tensile results obtained from "short-time" high-temperature test of ten different alumi-

num casting alloys and very pure cast aluminum, and for various heat treatments; all specimens tested were sand cast; tensile strength, yield point, elongation in 2 in., reduction in area, and Young's modulus values are given for various temperatures throughout range 75-800 deg. fahr.; describes method of measuring specimen temperatures during tensile tests.

AUTOMOBILES

FRONT AXLES—MANUFACTURE. How Ford Makes Front Axles, F. L. Faurote. *Iron Age*, vol. 122, no. 8, Aug. 23, 1928, pp. 457-460, 7 figs.

Method of forging and forming Ford front axles is outlined; after cutting to length, 40-in. forging machine is used to upset and bend each end, and 5000-lb. hammer and press are employed for blacking, finishing, and trimming; bench inspection follows, after which parts are heated in central section and bent and stretched to proper length in special press.

WELDING. Welding in the Ford Industries, M. L. Eckman. *Welding Jl. (Lond.)*, vol. 25, no. 298, July 1928, pp. 212-214, 5 figs.

Muffler assembly is ideal example of punch-press welding form of production assembly; wheels; battery-support assembly; steering gear, etc.; fan assembly; door and frames; fuel tank; equipment. Paper before Am. Welding Soc.

AUTOMOTIVE ENGINES

CRANKSHAFTS—STIFFNESS CALCULATION. Crankshaft Torsional Stiffness Subject of Analysis, B. C. Carter. *Automotive Industries*, vol 59, no. 8, Aug. 25, 1928, pp. 270-271, 1 fig.

Test data used by author gathered from 15 different crankshafts as used in aircraft, marine and automobile engines; latter deflected mainly by crank arms. From Engineering, July 13, 1928.

CYLINDERS—CHROMIUM STEEL. Nitrated Chrome Steel Cylinders, L. Guillet. *Foundry Trade Jl (Lond.)*, vol 38, no. 611, May 3, 1928, p. 314.

According to experiments, employment of nitrated steel for cylinders gives results never before attained; steel has hardness that produces unequalled durability and resistance; exhaustive tests showed virtually no wear in pistons, whether of cast steel or aluminum alloy; necessity for lubrication was diminished. Brief abstract of paper presented to Académie des Sciences.

AUTOMOBILE PARTS

MANUFACTURE. Unbreakable Automobile Components, J. W. Urquhart. *Machy. (Lond.)*, vol. 32, no. 826, Aug. 9, 1928, pp. 599-602, 2 figs.

Major causes of failure in parts of gear box, crankshaft, or steering transmission gear are outlined with explanation of how manufacturers are succeeding in averting most of them; forging and heat treatment of gear blanks and crankshafts; spray quenching; influence of grain, flow and fiber resistance.

AUTOMOBILE PLANTS

ELECTRIC FURNACES, HEAT TREATING. Dodge Electrifies Heat Treatment. *Iron Age*, vol. 122, no. 7, Aug. 16, 1928, pp. 389-392, 5 figs.

Detail of electric heat-treating furnaces used in plan of Dodge Brothers, Inc.; two separate heat-treating departments, one for finished machine parts and one for forging; over 60 furnaces drawing total current of 11,400 kw.; unique charging devices; one battery handles 450,000 lb. of rough forgings daily; hearth floor consists of three alloy plates locked at one end and alloy steel wall 10 in. high; heat is transmitted through alloy bottom.

HEAT TREATING DEPARTMENT.—Modernized Equipment for Heat Treating, F. W. Manker. *Heat Treating and Forging*, vol. 14, no. 4, Apr. 1928, pp. 386-387, 3 figs.

Mechanization in handling pieces in process of heat treating in forge and treating departments of Willys-Overland Co.; hardening miscellaneous parts; annealing after drop forging.

LABORATORIES (CADILLAC). "Craftsmanship a Creed—Accuracy a Law," L. A. Danse. *Mfg. Industries*, vol. 15, nos. 3 and 4, Mar. and Apr. 1928, pp. 207-210 and 283-284, 8 figs.

This is motto of Cadillac Co.; details of work on which high-class car and growing market are based; plant laboratory which tests materials and processes at every important stage of operations; five sections of chemical division in inspection and research laboratory handle extensive metallurgical investigations and tests, and carry on miscellaneous work; sixth section deals entirely with oil, grease and gasoline.

BEARING, BALL

MANUFACTURE. The Manufacture of Ball Bearings (La fabricacion de cojinetes de bolas), A. Lafont. *Ingeniería y Construction (Madrid)*, vol. 6, no. 67, July 1928, pp. 353-361, 24 figs.

Author inspected S.K.F. factory in Berlin; description of machinery and some details of successive steps in manufacture; no factory in Spain for ball bearings; cites general use of such bearing in France, England, Germany, and North America; advocates establishment of industry in Spain, emphasizing desirablility as preparation for national defense.

BEARING METALS

BRONZE—TESTING. Wearing and Mechanical Tests on Bearing Bronzes, H. J. French. *Rolling Mill Jl. (formerly Iron and Steel World)*, vol. 2, no. 8, Aug. 1928, pp. 417-418.

Abstract of paper presented before Am. Soc. Testing Matls., previously indexed.

RESEARCH. Bearing Metals, E. C. Wadlow. *Automobile Engr. (Lond.)*, vol. 18, no. 242, June 1928, pp. 221-225, 16 figs.

Practical investigation of load-carrying properties of bearing metals; research dealing with materials and lubricants as they are obtained commercially; tests to obtain information regarding suitability of cold-drawn and extruded tubes for plain journal bearings; microstructure and general performance; correlation of bearing factors with chemical and physical properties.

TESTING. Wear and Mechanical Tests of Some Railroad Bearing Bronzes, H. J.

French. *Am. Soc. Testing Matls.—Preprint*, no. 34, for mtg. June 25, 1928, 28 pp., 18 figs.

Copper-tin-lead alloys, both chill-cast and sand-cast, were tested under friction, without lubrication at varying temperatures; generally, chill-cast bronzes were less resistant to wear and notched-bar impact than sand-cast bronzes, but more resistant to pounding and tension; increase in lead, particularly in range 0.25 to 10 per cent, improved wearing properties but lowered resistance to pounding impact, and tension; increase in tin improved all properties.

TIN BASE. A Study of Tin-Base Bearing Metals, O. W. Ellis and G. B. Karelitz. *Metal Industry (Lond.)*, vol. 33, nos. 6 and 7, Aug. 10 and 17, 1928, pp. 132-134 and 156-158 and 162.

Abstract of paper read before Am. Soc. Mech. Engrs., previously indexed.

BERYLLIUM

Beryllium: A Survey, A. C. Vivion. *Min. Mag. (Lond.)*, vol. 38, no. 4, Apr. 1928, pp. 220-222.

Beryllium has some unique properties; continuous-furnace process yields cathode beryllium (99.8 per cent); much lighter than aluminum and practically as light as magnesium, while its hardness and probably its resistance to corrosion are superior to either; has high melting point of 1280 degrees Cent.; many uses; it is obtained from crude beryl containing but 4 to 5 per cent of metal by weight; development of applications for beryllium is in its earliest stages.

PROPERTIES. Thermal Expansion of Beryllium and Aluminium-Beryllium Alloys, P. Hidnert and W. T. Sweeney. *Metal Industry (Lond.)*, vol. 32, nos. 16 and 17, Apr. 20 and 27, 1928, pp. 397-400 and 423-424, 10 figs.

Investigation undertaken by Bureau of Standards gives results on linear thermal expansion of beryllium (98.9 per cent) and five aluminum-beryllium alloys containing various percentages of beryllium (4 to 33 per cent.)

BRASS

ANNEALING. Critical Temperatures in the Annealing of Brass, F. Osterman. *Fuels and Furnaces*, vol. 6, no. 4, Apr. 1928, pp. 517-519, 4 figs.

Annealing of brass wire within temperature range where alloy is in neighborhood of border line between alpha and alpha-plus-beta field often results in decrease in both ultimate tensile strength and ductility.

BRASS FOUNDRIES

FURNACE REFRACTORIES. Refractories for Brass Foundry Furnaces, H. M. St. John. *Am. Foundrymen's Assn.—Reprint*, no. 28-28, for mtg. May 14, 1928, pp. 439-452, 4 figs.

Supplements previous report by committee on Non-Ferrous Survey, subcommittee of Joint Committee on Foundry Refractories; classifies various types of brass foundry furnaces and discusses refractory experiences with each; indicates relative importance of refractory requirements in different furnaces and shows progress which is being made in meeting these requirements; emphasis is placed on desirability of improving average results to point where they more nearly approach best practice.

BRIDGES

ARC WELDING RAILROAD. Members Welded Into "One-Piece" Bridge. *Constr. Methods*, vol. 10, no. 7, July 1928, pp. 16-17, 7 figs.

Single-track bridge, 180 ft. long, which carries Boston and Maine Railroad over power canal at Chicopee Falls, Mass.; steel tonnage saving 33 per cent; outstanding advantage secured by use of arc welding; bridge was designed exclusively for arc welding details.

BRONZE

HARDNESS TESTING. The Hardness Value for Standard Tin Bronzes, Red Brass Alloys, and Lead-Tin Bronzes in Cast State (Zur Kenntnis der Haertwerte der genormten Zinn-Bronzen, Rotguss-Legierungen und Blei-Zinn-Bronzen in gegossenem Zustande), W. Claus, H. Goeke and F. Goederitz. *Giesserei (Duesseldorf)*, vol. 15, no. 31, Aug. 3, 1928, pp. 763-772, 19 figs.

Results of Brinell hardness testing; testing regulations for different alloys.

BRONZE, ANCIENT

METALLURGY. Contribution to the Metallurgical Study of Ancient Bronzes (Contribution à l'étude métallurgique des bronzes antiques), Butescu. *Annales des Mines (Paris)*, vol. 13, no. 3, Mar. 1928, pp. 177-191.

Old bronze implements found in Roumania were examined metallographically and their composition determined chemically.

BRONZE FOUNDING

Recent Developments in the Technique of Bronze Founding (Récent développements dans la technique de la fonderie de bronze), F. W. Rowe. *Fonderie Moderne (Paris)*, vol. 22, Apr. 10, 1928, pp. 131-135 and (discussion) 135-136.

Reverberatory furnaces reduce fusion costs; molding by centrifugal methods; new improvements; aluminum bronze.

CADMIUM PLATING

Cadmium Plating Finds Increasing Favor. *Eng. and Min. Jl.*, vol. 125, no. 25, June 23, 1928, p. 1015.

Growing demand for cadmium in plating industry is reported by producers; price has risen slightly as result; cadmium deposited on steel gives much better protection than zinc against attacks by atmospheric air and seawater; metal is harder than tin, little softer than zinc, and will take nice polish; cadmium deposit makes good base on which to plate nickel or other metals.

The Prevention of Corrosion by Electrodeposition, S. Wernick. *Indus. Chemist (Lond.)*, vol. 4, no. 41, June 1928, pp. 234-238, 3 figs.

Electrodeposition of cadmium and Udylite process; good cadmium electroplate represents one of very best means for preventing corrosion; properties of cadmium plate; production of efficient cadmium plate; cadmium content, etc.; anodes; action of corrosives. (Continuation of serial.)

CATALYSTS

IRON. Study of Action of Iron Catalysts on Mixtures of Carbon and Hydrogen Oxides (Etude de l'action des catalyseurs au fer sur

les mélanges d'oxyde de carbone et d'hydrogène), E. Audibert and A. Raineau. *Revue de l'Industrie Minérale (Paris)*, no. 182, July 15, 1928, pp. 286-314, 4 figs.

Choice of catalysts; working under pressure of iron-copper-alkali catalyst with research on improvement of this catalyst; working of ternary catalyst at low-temperature under low-pressure; study of catalyst in which iron appears as salt.

CASTING, CENTRIFUGAL

Diesel-Engine Parts Centrifugally Cast (Pieces moulées par centrifugation pour moteurs Diesel), J. E. Hurst. *Fonderie Moderne (Paris)*, vol. 22, May 25, 1928, pp. 193-198, 5 figs.

Describes centrifugal casting, its advantages, molds used, chemical composition; resistance of centrifugal-cast parts to wear and heat.

CAST IRON

ELECTRIC CONDUCTIVITY. The Electric Resistance of Cast Iron, H. Pinsl. *Foundry Trade Jl. (Lond.)*, vol. 38, no. 610, Apr. 26, 1928, pp. 303-304 and 306, 3 figs.

Investigations on electric resistance of cast iron of different composition furnished by several works; relationship between resistance and combined silicon and graphite contents; influence of structure; influence of cooling conditions. Translated from Giesserei-Zeitung (Berlin), Feb. 1, 1928, p. 73.

ELECTRIC WELDING. Cold Electric Welding of Cast Iron Machine Parts (La soudure électriques à froid de pieces de machines en fonte). *Pratique des industries Mecaniques (Paris)*, vol. 11, no. 1, Apr. 1928, pp. 21-22, 5 figs.

Describes methods used in various repair jobs on cast iron parts.

GRAPHITIZATION. Examples of Peculiar Graphite Crystallization in Pig and Cast Iron (Beispiele eigenartiger Graphitkristallisationen im Roh- und Guesseisen), H. Pinsl. *Stahl u. Eisen (Duesseldorf)*, vol. 48, no. 15, Apr. 12, 1928, pp. 473-477, 15 figs.

Metallographic indication of graphic eutectoid; formation of primary and disintegrating graphite in presence of iron phosphides.

GRAPHITIZATION. Graphite in Gray Cast Iron and Its Influence on Strength (Beitraege zur Kenntnis des Graphits im grauen Gusseisen and seines Einflusses ouf die Festigkeit), P. Bardenheuer and K. L. Zeyen. *Stahl u. Eisen (Duesseldorf)*, vol. 48, no. 16, Apr. 19, 1928, pp. 515-519, 59 figs. partly on supp. sheets.

Investigation of influence of overheating temperature on dissolution of graphite, on structure and graphite formation; relation of mechanical properties of cast iron to formation of graphite; influence of casting temperature on graphitization and strength of cast iron.

HEREDITY. The Heredity of Cast Iron (Au sujet de l'herédite des fontes) B. Buffet and H. Thyssen. *Revue Universele des Mines (Liége, Belgium)*, vol. 18, no. 1, Apr. 1, 1928, pp. 5-7, 1 fig.

Quotes facts which tend to prove that graphite in cast iron is great deal less soluble than is generally supposed; these facts which confirm views on heredity, show also that it is illogical to classify cast irons by their simple chemical analysis and that classifying pigs according to physical aspect of their fracture is not as illogical as it may seem.

RESEARCH. Cast Iron in Light of Recent Research, *Foundry Trade Jl. (Lond.)*, vol. 28, no. 612, May 10, 1928, p. 329.

Review of book under this title, by W. H. Hatfield (3rd edition), published by Chas. Griffin and Co., London. See also editorial comment, p. 327.

CAST IRON, GRAY

The Gray Iron Conference in Pittsburgh. *Mech. Engr.*, vol. 50, no. 5, May, 1928, p. 411.

Conference of gray iron foundrymen was called at Carnegie Institute, Pittsburgh, on Mar. 13, to consider conditions existing in jobbing part of gray iron industry and to discuss possible remedies; judging from various addresses made jobbing business in gray iron is falling upon evil days; speakers outlined substantially three ways of attacking problem.

CAST IRON, NICKEL

Nickel in Cast Iron, A. B. Everest. *Foundry Trade Jl. (Lond.)*, vol. 38, no. 608, Apr. 12, 1928, pp. 255-258, 3 figs.

Development of cast iron in general, and of nickel cast iron in particular; irons of low nickel content only are dealt with; methods of adding nickel to cast iron; influence of nickel on various ordinary foundry mixtures; results on nickel cast irons made from cupola-melted low-silicon bases; conclusions based on test. Includes photomicrographs and bibliography.

CAST IRON, PEARLITIC

Present Status of Pearlitic Iron, R. Moldenke. *Iron Age*, vol 121, no. 18, May 3, 1928, pp. 1241.

Pearlitic iron is similar to high-test irons; pearlite is grouping of alternate layers of pure iron and iron carbide; pearlitic iron falls in low-silicon ranges; silicon content and mold temperature chief factors involved; expert practical manipulation is required to get satisfactory results; pearlitic cast iron should only be made with separate melting installation and in special building.

CERAMIC MATERIALS

HEAT TRANSMISSION. Heat Transfer Through Ceramic Materials, M. Jakob. *Ceramic Age*, vol. 11, no. 4, Apr. 1928, pp. 121-130.

Importance of heat conductivity of ceramic products; method of determining heat conductivity values for heat conductivity and temperature conductivity; various influences affecting heat conductivity of ceramic products.

CHAINS

STRENGTH. Resistance of Metal Rings and Chains (Note sur la resistance des anneaux métalliques et des chaines), H. Gil. *Arts et Métiers (Paris)*, vol. 81, no. 93, June 1928, pp. 221-224, 2 figs.

Study of laws of deformation and strength of links of chains and tests made to determine their strength.

WROUGHT IRON—FAILURE. The Causes of Failure of Wrought-Iron Chains. *Foundry Trade Jl. (Lond.)*, vol. 38. no. 619, June 28, 1928, p. 484.

Investigation to determine cause of brittle failure of wrought-iron chain; heat treatment; low temperature annealing or normalizing, has been shown, by causing recrystallization in hardened surface layers, to restore original ductility. Abstract of report published by Dept. of Sci. and Indus. Research.

CHROMIUM

PLATING. Porosity of Electrodeposited Chromium, E. M. Baker and A. M. Rente. *Am. Electrochem. Soc.—Advance Paper, for mtg.* Sept. 20-22, 1928, pp. 117-125, 5 figs.

Study made of porosity of chromium deposited from chromic-acid chromium-plating baths; findings of other workers have been confirmed and extended; nature and cause of porosity of electrodeposited chromium are discussed in some detail.

CHROMIUM PLATING

PREPARATION. Polish Essential for Chromium Plate, C. H. Eldridge. *Iron Age,* vol. 121, no. 24, June 14, 1928, pp. 1680-1682, 4 figs.

Details of successful methods of General Chromium Corp. for preparation of rough casting or stamping, undercoat of nickel and final chromium plate; chromium plate reproduces defects in surface; speed of lathes; rough cast or forged steel needs preliminary smoothing, brass castings need finer finish; preparation of pressed steel sheet, nickel and copper-plate surfaces; soft die-cast metal, white metal, and nickel brasses.

PROTECTIVE VALUE. Protective Value of Chromium-Plate. E. M. Baker and W. L. Pinners. *Soc. Automotive Engrs.—Jl.,* vol. 23, no. 1, July 1928, pp. 50-51.

Discussion of annual meeting paper, with brief abstract of paper; desirability of exposure tests; adherent plating requires clean base steel; chromium plating on tools and gages; successful on light-load bearings.

CHROMIUM STEEL

CORROSION TESTING. Electrochemical Behavior and Corrosive Properties of Chromium Steels (Elektrochemisches Verhalten und Rostneigung von Chromstaehlen), O. Meyer and K. Roesch. *Archiv fuer das Eisenhuettenwesen (Duesseldorf).* vol. 2, no. 2, Aug. 1928, pp. 119-125, 9 figs.

Notes on corrosion and single potential; behavior of rustless chromium steels in neutral and acid solutions; relation of single potential to pretreatment; influence of carbon content on corrosive tendency.

CHROMIUM-COPPER STEEL

The Development of High-Grade Structural Steel (Zur Fortentwicklung des hochwertigen Baustahles), K. v. Kerpely. *Stahl und Eisen (Duesseldorf),* vol. 48, no. 33, Aug. 16, 1928, pp. 1130-1132.

Author takes exception to certain points in article by E. H. Schulz in previous issue of this journal (p. 449, 1928), describing new type of structural steel developed by Dortmunder Union der Vereinigten Stahlwerke). He does not believe that chromium-copper steel discussed by Schulz represents any improvements; includes reply by Schulz.

CHROMIUM-NICKEL ALLOYS

Laboratory Experiments on High-Temperature Resistance Alloys, C. J. Smithells, S. V. Williams and J. W. Avery. *Inst. of Metals—Advance Paper (Lond.),* no. 466, for mtg., Sept. 4-7, 1928, 22 pp., 17 figs.

Nickel-chromium alloys containing 10 to 60 per cent of chromium and ternary alloys containing tungsten and molybdenum were subjected, together with commercial nickel-chromium alloys, to new forms of test for resistance to oxidation and sag at high temperatures; presence of small amounts of impurities has marked effect; commercial alloys are inferior to experimental alloys for this reason.

CHROMIUM ORE—RHODESIA

The Chrome Industry of S. Rhodesia. *S. African Min. and Eng. Jl. (Johannesburg),* vol. 39, no. 1919, July 7, 1928, pp. 539-542, 2 figs.

Southern Rhodesia is world's largest producer of chrome; bulk of ore comes from Selukwe district; Lomagundi or Umvukwes fields also yield considerable; Selukwe deposits believed to contain enough to satisfy world demand for years; table of production, 1907 to 1927 inclusive.

COPPER

FATIGUE. A Metallographic Study of the Path of Fatigue Failure in Copper, H. F. Moore and F. C. Howard. *Metal Industry (Lond.),* vol. 32, no. 24, June 15, 1928, pp. 589-592, 9 figs.

Reprint of paper published in Univ. of Ill.—Bul., No. 37, 1928, previously annotated.

METALLOGRAPHY. Diffusion of Zinc into Copper, S. L. Hoyt. *Am. Inst. of Min. and Met. Engrs.—Tech. Publication,* no. 128 Aug. 1928, 4 pp., 2 figs.

Brief description of investigation of thin copper strips coated with zinc; tabulation and graphs on results as to time and temperature of heat treatment causing zinc to penetrate and diffuse itself into copper.

METALLOGRAPHY—GAS ABSORPTION. Absorbability of Gases in Casting Copper and Effect of Adding Cuprosilicon, O. W. Ellis. *Am. Inst. of Min. and Met. Engr.—Tech. Publication,* no. 123, Aug. 1928, 26 pp., 18 figs.

Solubility of gases in copper; solubility of water vapor in copper; experiments by melting in electric and oil-fired furnaces; metallographic examination of ingots; tabulation of results, under varying melting conditions; conclusions enumerated.

WELDING. Welding Copper (Das Schweissen von Kupfer und seinen Legierungen), Kalisch. *Zeit. fuer Angewandte Chemie (Berlin),* vol. 41, no. 14, Apr. 7, 1928, p. 361.

Copper (or brass or bronze) can be successfully welded by pressure-welding method; procedure is described.

COPPER ALLOYS

Useful Copper Alloys, W. H. Basset. *Mech. World (Lond.),* vol. 84, no. 2171, Aug. 10, 1928, p. 127.

Abstract of paper presented before Inst. of Metals (United States) and previously in-

dexed in Metal Industry (Lond.), May 25, 1928.

HEAT TREATMENT. The Effect of Heat Treatment on Some Mechanical Properties of 85:5:5:5 Copper-Tin-Lead-Zinc Alloy, R. J. Anderson. *Am. Metal Market*, vol. 35, no. 111, June 12, 1928, pp. 9-12, 28 and 46, 10 figs.

Results of experiments with two alloys, viz., 85:5:5:5 and 85:4:5:6 copper-tin-lead-zinc, object of investigation was to determine effects of annealing and of quenching on tensile properties of alloys as sand cast; microscopic examination. Bibliography.

HEAT TREATMENT. A Rejoinder to Dr. R. J. Anderson's Articles on the Heat Treatment of Copper-Tin Bronzes, C. H. Bierbaum. *Am. Metal Market*, vol. 35, no. 34, Feb. 21, 1928, p. 7.

Difficult to see how any copper-tin bronze, aside from that of bearing metals, can economically compete with certain alloys; various concerns in effort to improve their copper-tin bronzes for bearing purposes, have resorted to heat treatment in order to meet ever increasing punishment in service. Includes reply by R. J. Anderson.

HEAT TREATMENT. The Effect of Heat Treatment on Some Mechanical Properties of 90:6:3:1 Copper-Tin-Zinc-Lead Alloy, R. J. Anderson. *Am. Metal Market*, vol. 35, no. 55, Mar. 22, 1928, pp. 3-5, 19 figs.

Metallographic constitution of alloy; prior work on copper-tin-lead-zinc alloys; microscopic examination; method of investigation; uses of this alloy; selected bibliography.

COPPER ALLOYS, HEUSLER

PROPERTIES. Properties of Heusler Alloys. Manganese-Aluminum-Copper Alloys (Zur Kenntnis der Heusler'schen Legierungen. Ueber das Mangan-Aluminum-Kupfer), O. Heusler. *Zeit. fuer anorganische u. allgemeine Chemie (Leipzig)*, vol. 171, no. 1-2, Apr. 13, 1928, pp. 126-142, 17 figs.

Constitution of ferromagnetic manganese-aluminum-copper alloys; properties of alpha and beta ternary crystals and mixtures of them; theory of ferromagnetic state and of aging of alloys.

WORKING. Workable Manganese-Copper Alloys (Ueber verguetbare Mangankupferlegierungen), F. Heusler and E. Doennges. *Zeit. fuer anorganische u. allgemeine Chemie (Leipzig)*, vol. 171, no. 1-2, Apr. 13, 1928, pp. 146-162, 8 figs.

Progress in development of Heusler alloys of manganese, copper and aluminum; effect of aging on hardness and electric conductivity.

COPPER-MAGNESIUM ALLOYS

The Copper-Magnesium Alloys, W. R. D. Jones. *Inst. of Metals—Advance Paper (Lond.)*, no. 469, for mtg. Sept. 4-7, 1928, 11 pp., 5 figs.

Paper deals with notched-bar impact test on forged and heat-treated alloys; there is no advantage in adding more than 2 per cent of copper to magnesium; alloys containing more than 5 per cent are brittle; on exposure to cold, toughness has been decreased; simple heat treatment does not improve notched-bar impact values to any appreciable extent; effect of forging on microstructure has been to break down eutectic network, resulting in improvement of mechanical properties.

COPPER-NICKEL ALLOYS

Copper-nickel Alloys. *Machy. (Lond.)*, vol. 32, no. 821, July 5, 1928, pp. 450-451.

Properties and industrial applications of copper-nickel alloys; addition of relatively small amounts of nickel increases hardness of copper and its resistance to oxidation at elevated temperatures; influence of carbon, sulphur, and manganese; corrosion-resisting property.

COPPER-NICKEL CASTINGS

SPECIFICATIONS. Proposed Master Specification For Copper-Nickel Alloy Castings. *Foundry*, vol. 56, nos. 15 and 16, Aug. 1 and 15, 1928, supp. sheets, nos. 727, 728 and 729, 1 fig.

Aug. 1, United States Government general specification for metals, Federal Specifications Board Specification No. 339, in effect on date of invitation for bids, forms part of this specification; general and detail requirements of material, and method of inspection and tests given. Aug. 15: Inspection; packing and marking of shipment.

COPPER-SILICON ALLOYS

The Alpha-Phase Boundary of the Copper-Silicon System, C. S. Smith. *Inst. of Metals—Advance Paper (Lond.)*, no. 476, for mtg. Sept. 4-7, 1928, 12 pp., 4 figs.

Alpha-phase boundary has been redetermined by series of annealing and quenching experiments; solubility reaches its maximum value, 6.7 per cent silicon, between 721 and 782 deg. cent.; at 852 deg., temperature of peritectic horizontal, solubility is 5.25 per cent, while at 400 deg. is only 4.1 per cent silicon.

COPPER-ZINC ALLOYS

Copper-Zinc Alloys. *Metallurgist (supp. to Engineer, Lond.)*, Apr. 27, 1928, pp. 50-52, 2 figs.

Review of three articles, as follows: Examination of Diagram of State of Copper-Zinc system, D. Kitsuka, in Zeit. fuer Metallkunde, vol. 19, 1927, p. 396; Hardness and Electrolytic Potential of Copper-Zinc Series, O. Bauer and O. Vollenbruch, in Zeit. fuer Metallkunde, vol. 19, 1927, p. 86; and book by Bauer and Hausen, which is monumental study of constitution of whole system.

COPPER METALLURGY

Progress in Metallurgy of Copper and Lead in 1927 (Los progresos en la metalurgia del cobre y plomo en 1927). *Boletin Minero (Santiago, Chile)*, vol. 40, no. 345, Jan. 1928, pp. 17-18.

Copper smelters exchange information and avoid publication, due to Carson litigation; Andes copper, Potrerillos, Chile, and Horne smelter at Noranda, Canada, fired up; various notes on copper; flotation progress changes lead-smelting practice; concentrates richer, with less zinc; Phelps Dodge construction at Douglas, Ariz.; National Lead installed refinery at Buenos Aires.

COPPER SMELTING PLANTS

QUEBEC. The Horne Copper Mine and Smelter at Noranda, Quebec. *Engineer (Lond.)*, vol. 145, no. 3769, Apr. 6, 1928, p. 376, 5 figs. (4 on p. 378.)

Smelter plant is largest mining building in Northern Canada; both "custom" ore and

ore from Horne mine are to be treated at smelter; separate bins are provided for each of two classes; ores will be crushed in three stages; smelting process will be carried on in reverberatory smelting furnaces.

CUPOLAS

TEMPERATURE RECORDERS. Recording the Cupola Temperature, H. W. Dietert. *Can. Foundryman (Toronto)*, vol. 19, no. 4, Apr. 1928, pp. 12-13, 3 figs.

Cupola temperature recorder consists of three parts, hood, thermocouple and recorder, and is adaptable to any heat; causes of irregular temperatures; use of device on hand-charged cupola; result of low coke bed; check of standard practice.

DIE CASTING

ALUMINUM ALLOYS. Properties and Production of Aluminum Alloy Die-Castings, S. L. Archbutt, J. D. Grogan and J. W. Jenkin. *Inst. of Metals—Advance Paper (Lond.)*, no. 477, for mtg. Sept. 4-7, 1928, 19 pp., 19 figs.

Investigation of die castings made in permanent metal molds under gravity feed, i.e., without application of external pressure and hot-shortness of aluminum die-casting alloy; two types of casting were investigated: (1) shouldered test piece of circular section suitable for testing direct without machining; (2) hollow tubular casting requiring use of cores in molding; to overcome defects due to air locks, shrinkage, etc., careful control of working conditions was necessary.

COPPER ALLOYS. Die-Casting of Copper-Rich Alloys, R. Genders, R. C. Reader and V. T. S. Foster. *Inst. of Metals—Advance Paper (Lond.)*, no. 475, for mtg. Sept. 4-7, 1928, 32 pp., 6 figs.

Exploratory examination of wide range of alloys in form of chill-cast bars and die-cast test pieces has indicated that variety of alloys exist suitable for die casting and offering mechanical properties to meet varying requirements; aluminum brasses have advantages in their range of properties, high proof stress, slow rate of attack on mold and core materials, and cheapness.

DIESEL ENGINES

PULVERIZED FUEL. Coal Dust for Oil in Engines as in Boilers, R. Pawlikowski. *Coal Age*, vol. 33, no. 8, Aug. 1928, pp. 489 and editorial, p. 495, 1 fig.

In 1911 Kosmos Machine Works of Goerlitz, Germany, began experiments on pulverized-coal engine; successful in 1916; engine in regular operation and piston rings not replaced until 1924; for 12 years it operated with nearly all grades of German anthracite; will also run on oil, mixture of oil and pulverized coal, or on turf, sawdust, charcoal, rice dust, flour, and even coke. Previously indexed from Power, July 24, 1928.

TESTING. Some Tests on a Two-Stroke Cycle Diesel Engine, E. A. Allcut. *Power House (Toronto)*, vol. 22, no. 16, Aug. 20, 1928, pp. 24-26, 6 figs.

Tests were performed on vertical oil engine installed in thermodynamic laboratory of University of Toronto; standard type of two-stroke cycle heavy-oil engine, having hot-bulb ignition and crankcase compression; cylinder has bore of 9½ in., stroke 11 in.; rated power 25 b.hp. at speed of 375 r.p.m.; test results.

DILATOMETERS

The Dilatometer and Its Application. *Am. Mach.*, vol. 68, no. 25, June 21, 1928, p. 1019, 3 figs.

Operation details of dilatometer by means of which correct quenching temperature is mechanically indicated regardless of type of steel; by arrangement of recording chart to show amount of expansion during heating period, rate of heating is also definitely recorded; by comparison with known rates for steels, proper heating rate for given steel can be controlled.

DROP FORGING

ACCIDENT PREVENTION. Safety Problems in the Forge Shop, J. C. MacLagan. *Heat Treating and Forging*, vol. 14, no. 6, June 1928, pp. 622-623.

Importance of safety problem in drop forge industry is emphasized; safety in small plant; mercenary viewpoint; incidental or hidden cost of accidents; some of items that enter into incidental costs. Paper delivered at Am. Drop Forge Convention.

DURALUMIN

ALCLAD. Aluminum-Coated Duralumin Proves Durable Aircraft Material, T. W. Downes. *Automotive Industries*, vol. 59, no. 7, Aug. 18, 1928, pp. 238-241, 5 figs.

Alclad stands up especially well against corrosion in salt spray test after anodic oxidation treatment; resistance to elements high even when surface is scratched; Alclad is sheet consisting of strong aluminum alloy upon surfaces of which is superimposed relatively thin layer of aluminum of high purity; metallurgical investigation of Alclad at Naval Aircraft factory.

PROTECTIVE COATINGS. Protective Coatings for Duralumin and other Aircraft Alloys, H. A. Gardner. *Am. Paint and Varnish Mfrs. Assn.*, no. 330, June 1928, pp. 482-508, 13 figs.

Exposure tests upon laboratory roof have been continuous since start of tests; final inspection results; materials used and methods of exposure; report of recent inspection and conclusions which have been reached.

ELECTRIC MEASURING INSTRUMENTS

PRECISION. Measuring a Billionth of an Inch. *Metal Industry (N. Y.)*, vol. 26, no. 6, June 1928, p. 272.

Equipment to measure changes in length of order of billionth of inch has recently been devised by P. P. Cioffi of Bell Telephone Laboratories; this length is just about one-tenth of diameter of atom; need for so refined instrument arose from studies of magnetic materials.

FOUNDRIES

MATERIALS HANDLING. Automatic Handling in the Foundry (La manutention automatique en fonderie), A. O. J. Malengreau. *Fonderie Moderne (Paris)*, vol. 22, Aug. 10, 1928, pp. 303-305, 1 fig.

Systems used for handling materials and ap-

paratus in foundry are described; hand work is discussed and compared with machine work.

MATERIALS HANDLING. Study Your Returns from Handling Equipment, J. J. Hartley. *Foundry*, vol. 56, no. 16, Aug. 15, 1928, pp. 673-674.

Problem of applying materials-handling equipment to foundry and determining its earnings is discussed; common-sense use of simple accounting methods, coordination of plan with production requirements, careful estimating entire cost of proposed equipment, and conservative estimate on returns are all necessary. Abstract of paper presented before Am. Foundrymen's Assn.

FOUNDRY PRACTICE

OXYACETYLENE WELDING. Oxy-Acetylene Welding in the Foundry, G. F. Wieser. *Acetylene Jl.*, vol. 30, no. 2, Aug. 1928, pp. 59-62.

Welding torch is important factor in assisting up-to-date foundryman to keep costs down, to make deliveries of sound well-finished castings; oxyacetylene-welding process possesses characteristics which make it peculiarly and increasingly applicable in nonferrous, gray-iron and steel foundries; defects in steel castings; shows important part which oxyacetylene welding plays in enabling foundryman to meet customer's specifications. Paper read before Welding Conference.

PURCHASING. Foundry Purchasing, E. N. Simons. *Foundry Trade Jl. (Lond.)*, vol. 39, no. 625, Aug. 9, 1928, p. 100.

Handling goods; saving transport costs; classification of incoming materials; importance and methods of modern weighing office; why goods should be weighed.

REVEBERATORY. Rational Operation of Oil-Fired Reverberatory Furnaces (Rationelle Fuehrung von oelgeheizten Flammoefen), E. Zimmermann. *Zeit. fuer die gesamte Giessereipraxis (Berlin)*, vol. 49, nos. 30 and 31, July 22 and 29, 1928, pp. 253-256 and 261-263.

Theory and practice of oil firing; determination of calorific value of liquid fuels; combustion process; influence of air volume on character of flame and combustion; calculation of air required; atomization of fuel oil.

GAS FUELS

COMBUSTION TEMPERATURE. The Influence of Nonvolatile Constituents on the Theoretical Combustion Temperature of Gaseous Fuels (Ueber den Einfluss nichtverbrennender Bestandteile auf die theoretische Verbrennungstemperatur gasfoermiger Brennstoffe), F. Schuster. *Waerme (Berlin)*, vol. 51, no. 24, June 16, 1928, pp. 427-429.

Calculation of theoretical combustion temperatures; influence of carbonic acid, water vapor and diatomic gases; combustion of carbon monoxide with oxygen and air; influence of nitrogen and carbonic acid.

GEARS AND GEARING

BEVEL. New Type of Conical Gears and Their Rapid Cutting by a Special Miller (Un nouveau type d'engrenages coniques sa taille rapide au moyen d'une fraise speciale), R. Leguillochet. *Technique Moderne (Paris)*, vol. 20, no. 14, July 15, 1928, pp. 488-489, 4 figs.

Describes new type of bevel gear which can be cut on ordinary milling machine by means of simple set-up.

GRINDING WHEELS

HARDNESS. Study of Hardness of Grinding Wheels (Untersuchung der Schleifscheibenhaerte), M. Kurrein. *Werkstattstechnik (Berlin)*, vol. 2, no. 10, May 15, 1928, pp. 293-298, 20 figs. partly on supp. plates.

Review of experiments on glazing effect; photographic studies of texture and structure of grinding wheels, wearing effect due to grinding.

GUNITE

"Gunite"—Its Properties and Applications. *Machy. (N. Y.)*, vol. 35, no. 1, Sept. 1928, pp. 61-62, 3 figs.

New metal known as Gunite recently announced by Gunite Corp. of Rockford, Ill., is described; metal does not exhibit ductility of malleable iron or steel and shrinkage is less than one part in one thousand as result of heat treatment; micrograph compared with those of cast iron and semi-steel; no tendency to form hard outer skin; fredoom from internal strains; ability to resist wear under friction; tests made at Armour Institute of Technology.

INGOT STEEL

PROPERTIES. Stable Ingot Steels. (Flusstahl mit geringer Alterungseigenschaft), O. Bauer. *Zeit. des Bayrischen Revisions-Vereins (Munich)*, vol. 32, nos. 3 and 4, Feb. 15 and 29, 1928, pp. 23-31 and 41-44, 22 figs.

Study of special Krupp steels for use in boiler construction; effect of cold working and various annealing temperatures on notch impact strength; microstructure, chemical composition and notch impact tests of "Izett I" steel showing greater strength stability, annealing temperatures having less effect on toughness of this steel.

IRON

ANALYSIS. Diphenylamine as Indicator in the Titration of Iron with Dichromate, F. J. Watson. *Chem. Eng. and Min. Rev. (Melbourne)*, vol. 20, no. 238, July 5, 1928, pp. 355-357.

Reviews method of J. Knopp, as in Jl. Am. Chem. Soc., vol. 44, 1928, p. 263; describes series of titrations, followed electrometrically; concludes that diphenylamine can be satisfactorily used, provided that certain enumerated rules are observed.

INCLUSIONS. Inclusions in Iron—A Photomicrographic Study, C. R. Wohrman. *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 3, Sept. 1928, pp. 385-414, 44 figs.

Notes on oxide-sulphide inclusions; in presence of sulphur and oxygen in pure iron, both oxides and sulphides of iron are formed; manganese, if present in small amounts will combine primarily with oxygen; complex oxide-sulphide inclusions exhibit varying structures depending on heat treatment given to including metal; etc.

TESTING. Procedure for Simplified Testing, G. D. Johnson. *Heat Treating and Forging*, vol. 14, no. 8, Aug. 1928, pp. 870-874, 3 figs.

Description of methods of making simple tests to differentiate types of steel, to locate defects, and to check results of various heat treatments; determination of grade by spark test consists of observation of stream of sparks produced by grinding steel and classifying material through comparison of appearance of spark with some standard; shear test and application of deep etching for defects; tests for decarbonization.

X-RAY ANALYSIS. Japanese Scientists Study Crystal Lattice of Martensite. *Iron Age*, vol. 122, no. 9, Aug. 30, 1928, p. 515.

Brief review of results of investigation by S. Sekito published in Science Reports of Imperial Tohoku University, June 1928; he finds that space lattice of quenched 1-per cent carbon steel is 0.45 per cent greater than of quenched carbon-free iron.

STAINLESS STEEL

AUTOGENOUS WELDING. The Autogenous Welding of Stainless Steels, H. Bull and L. Johnson. *Engineering (Lond.)*, vol. 125, no. 3249, Apr. 20, 1928, p. 478.

Points out desirability, wherever possible, of subsequently heat treating all stainless-steel articles, after having welded them; all processes in use for welding of ordinary steel could be applied to welding of stainless material; in arc and gas welding, however, special electrodes or rods were necessary. Abstract of paper read before Brit. Acetylene and Welding Assn.

STAYBOLTS

MANUFACTURE. Staybolt Production in Railway Shops. *Boiler Maker*, vol 28, no. 2, Feb. 1928, pp. 33-37, 9 figs.

Proper threads, inspection system, gages, fixtures and machines best suited for this work; shape of thread; U. S. form of thread is gradually replacing all other forms for staybolt threading; gaging pitch diameter error in lead of staybolt taps; errors in staybolt threading; gaging pitch diameter of staybolts; flexible staybolts. (To be continued.)

STEAM TURBINES

BLADES. Metals for Steam-Turbine Blades Ein Beitrag zur Baustoff-Frage der Dampfturbiren-Beschaufelung), E. A. Kraft *Elektrotechnik u. Maschinenbau (Vienna)*, vol. 46, no. 14, Apr. 1, 1928, pp. 301-305, 9 figs.

Properties, resistance to cavitation, tension and impact tests of low nickel-steel (5 per cent nickel) and non-corrosive steel; use of hydrogen welding in steam-turbine construction.

STEEL CASTINGS

Steel Castings Withstand Severe Operating Conditions, J. H. Hall. *Foundry*, vol. 56, nos. 16 and 17, Aug. 15, and Sept. 1, 1928, pp. 655-656 and 702-704.

Aug. 15: So far as author is aware, no steel or iron yet has been found that will resist pure abrasive wear unaccompanied by pressure as satisfactorily as manganese steel; uses of nickel-chrome steels; greatest advance made in field of heat-treated castings of high strength and toughness for resisting heavy stresses. Increase of physical properties by use of additional alloys to special steels; work in high-temperature field. Abstract of paper presented in behalf of Am. Foundrymen's Assn. before Inst. of Brit. Foundrymen.

Steel Castings for Severe Service, J. H. Hall. *Foundry Trade Jl. (Lond.)*, vol. 39, no. 620, July 5, 1928, pp. 4-6.

Summary of recent American practice; limitations of manganese steel; composite steels; high-resistance heat treated castings; industrial applications; heat-resisting steel castings; stainless steels and irons. See also discussion, by R. Hadfield, in no. 621, July 12, pp. 31-32 and 34.

Putting Cast Steel Where It Belongs. *Research Group News*, vol. 5, no. 2, July 1928, pp. 190-197, 11 figs.

Feature of A. F. A. Convention in Philadelphia was large collection of castings; in steel section of this exhibition there were groups of castings from 18 companies; presents photographs of number of exhibit castings and supplements them with pictures of particularly interesting castings that were not at time available for exhibition.

DEFECTS. Casting of Steel Cracks (La fonderie d'acier, les criquex), M. Guèdras. *Fonderie Moderne (Paris)*, vol. 22, June 10, 1928, pp. 223-224.

Causes of cracks and fissures in steel castings and remedies for them treated briefly.

HEAT TREATMENT. Heat Treatment of Forgings and Castings for Selective Directional Adjustment of Residual Stresses, W. J. Merten, *Am. Soc. Steel Treating—Trans.*, vol. 14, no. 2, Aug. 1928, pp. 193-198, 3 figs.

Methods of selective abstraction of heat or selective cooling by directed quenching for producing favorable directional internal or residual stresses in forged disks or cast parts of rotating bodies; directing of coolant upon middle of rotating hollow bored or forged disk by properly placed spraying nozzles or by enclosing red-hot disk in container, immersing same into coolant and simultaneously opening ports and rotating disks.

MANUFACTURE. The Making of Steel Castings in 1927, F. Hodson. *Blast Furnace and Steel Plant*, vol. 16, no. 7, July 1928, p. 926.

A brief enumeration of manufacturing processes, chemical composition and properties; cooperation between consumer and maker urged; heat treating enhances service of castings.

PRODUCTION STATISTICS. Continued Heavy Production of Steel Castings. *Iron Age*, vol. 122, no. 4, July 26, 1928, p. 226.

Production of commercial steel castings in June is reported by U. S. Department of Commerce at 90,202 net tons; production for first six months has reached 523,745 tons.

SHRINKAGE. The Shrinkage of Cast Steel, F. Korber and G. Schitzkowski. *Foundry Trade Jl. (Lond.)*, vol. 39, no. 622, July 19, 1928, pp. 47-48, 3 figs.

Experiments were carried on with plain round bars; with bars with large flanges which hindered shrinkage, and with bars with flanges, shrinkage of which was limited by rigid iron rods put into mold; experiments with acid steel and using basic open-hearth steel. Abstract translated from Stahl und Eisen, 1928, nos. 5 and 6.

STEEL FOUNDRIES

LABORATORIES. Establishes Steel Foundry Laboratory. *Iron Age*, vol. 122, no. 5, Aug. 2, 1928, pp. 280-281, 2 figs.

Laboratory of East Chicago, Ind., plant of American Steel Foundries, equipped for production of experimental steels and alloys; heat treatment can be followed up under exacting conditions; two melting furnaces provided, one of carbon-pile resistance type, and other induction furnace; after production and heat treatment, properties of these alloys can be examined chemically microscopically and physically.

STEEL FOUNDRY PRACTICE

Steel Foundry Practice, P. Longmuir. *Iron and Steel Industry (Lond.)*, vol. 1, no. 11, Aug. 1928, pp. 357-358.

Basic steel making, both by open hearth and by Bessemer processes, and, in particular, with function of slag in basic open-hearth process, is described. (Continuation of serial.)

SOUTH AFRICA. Steel Casting as Applied to Shoe and Die Manufacture, J. D. Dunlop. *S. African Eng. (Lond.)*, vol. 39, no. 8, Aug. 1928, pp. 173-175.

Operations of Witwatersrand Co-operative Smelting Works at Driehoek, South Africa. Abstract of paper presented before S. African Instn. of Engrs.

STEEL MANUFACTURE

ELECTRIC PROCESS. Electrometallurgy of Steel for Foundry Use, R. J. Richardson. *Iron and Steel of Can. (Gardenvale, Que.)*, vol. 11, no. 8, Aug. 1928, pp. 232-237, 10 figs.

Brief comparison between electric and converter steels is given; electric conversion costs are higher in fuel refractories and electrodes; converter uses more expensive scrap and has higher melting loss, but has fair advantage generally; converter steel often has dissolved oxides present; electric steel will in future more than hold its own, and become universal; table of test results on electric steel castings.

STRAIN GAGES

Eliminating Error With Spherical Points On Straingage Levers, P. J. McCullough. *Instruments*, vol. 1, no. 6, June 1928, pp. 285-286, 2 figs.

Modification of shape of points by changing from cone or chisel point to ball point; steel balls 3/32 in. in diameter are secured by fusion; greatly reduces errors especially on test pieces with rough surfaces.

STRESSES

MODEL TESTING. Experimental Static Determination of Hyperstatic Systems (Determinacion estatica experimental de los sistemas hiperestaticos), J. M. Aguirre and A. San Roman. *Revista de Obras Publicas (Madrid)*, vol. 76, no. 2501, May 15, 1928, pp. 178-181, 5 figs.

German professor, C. Rieckhof, devised apparatus called "Nupubest"; series of parts that permit reproduction of structure in miniature and practical testing of comparative effects of concentrated and distributed loads on structure; example and graph of deformations obtained in study on platform for sports field at Seville exposition. See Bauingenieur, Feb. 24, 1928.

STRENGTH TESTING. Prolonged Stress and structure of Steel (Dauerbeanspruchung Gefuege und Daempfung), W. Herold. *Archiv fuer das Eisenhuettenwesen (Duesseldorf)*, vol. 2, no. 1, July 1928, pp. 23-38, and (discussion) 38-39, 36 figs.

Results of prolonged tests on annealed pearlitic and hardened martensitic and austenitic steels; determination of endurance strength; investigation of artificial and natural fractures.

A NEW DEVELOPMENT IN CORROSION-RESISTING STEEL

(*Continued from Page 892*)

them. Very often the surface of a piece of corrosion-resisting steel is innoculated with particles from the tools which have been used to finish it. They may have come from an emery wheel loaded with ordinary carbon steel and the wheel will drive the particles of carbon steel into the surface. Sometimes people prepare specimens for corrosion tests with a file, and you have but to file a piece of this high chromium steel with a brand new file to feel the splinters chip off the edge of the file. And where do the splinters go if they do not go into the surface being filed?

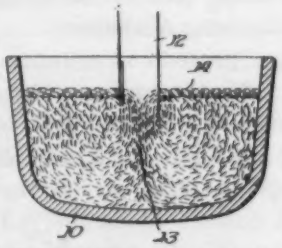
I have seen punched holes which have corroded around the wall of the hole and it was nothing in the world but tool steel particles wiped off the sides of the punch, because if you give the sample a dip in nitric or muriatic acid to remove the occluded iron the corrosion will cease. This point is worth emphasis because it frequently enters into our corrosion tests and explains many of the discrepancies which perplex us.

Reviews of Recent Patents

By NELSON LITTELL, Patent Attorney
475 Fifth Ave., New York City—Member of A. S. S. T.

1,684,841, September 18, 1928, Steel and Its Manufacture, Joseph Russell Cornell Marsh, of Arlington Heights, Illinois, Assignor to Francis Norwood Bard, of Chicago.

This patent describes the process of introducing a modifying element into steel, such as carbon, which comprises disposing the carbon particles in the form of flake or needle graphite in the bottom of the crucible 10 and flowing the molten metal thereinto in a stream 12 which sets up a circulatory motion of the graphite flakes in the stream, causing rapid dissemination of the same throughout the mass of molten metal and permitting the



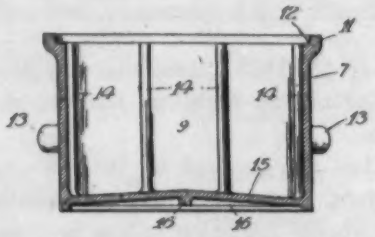
same to be quickly and uniformly absorbed therein. During the pouring operation, part of the graphite particles form a layer 14 on the top of the metal, protecting it from oxidization, but at the same time this top layer is drawn into the stream of molten metal as illustrated. It is desirable before pouring the metal into the ladle 10 to heat the same to a red heat to prevent chilling of the metal and facilitate absorption of the graphite therein.

1,685,570, September 25, 1928, Process of Improving the Qualities of Nickel-Beryllium Alloy, George Masing, of Berlin, and Otto Dahl, of Berlin-Charlottenburg, Germany, Assignors to Siemens and Halske, Aktiengesellschaft, of Siemenstadt, Near Berlin, Germany.

This patent is based upon exhaustive experiments which show that nickel-beryllium alloys, containing preponderating amounts of nickel, can be commercially produced and provide excellent technical properties, particularly with reference to hardness. An alloy of 13.4 per cent of beryllium is so hard that is scratches glass and, in general, the hardness of the alloy increases with the amount of beryllium. It is possible, however, to increase the hardness of alloys of a lower beryllium content by proper heat treatment as the hardness of the 5 per cent beryllium alloy can be substantially doubled by quenching in water or cooling in air from a temperature above 1300 degrees Fahr. and afterward tempering to a temperature of 600 to 1100 degrees Fahr. Further hardness can be imparted by mechanical working after quenching and prior to the second heating.

1,685,966, October 2, 1928, Annealing Pot, Robert S. Stewart, of Chicago, Assignor to The American Brake Shoe and Foundry Company, of New York City, a corporation of Delaware.

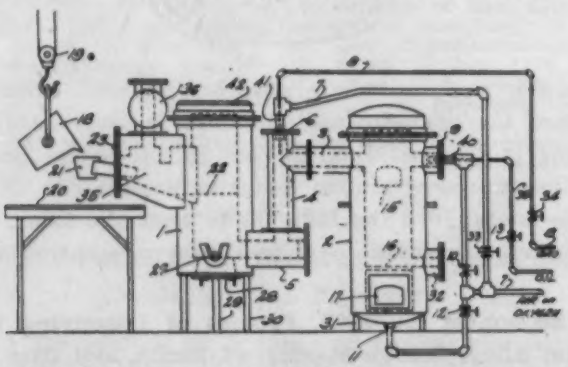
This patent describes an annealing pot 7, having corner walls of greater thickness than usual to withstand the corner strains, and provided with



longitudinal reenforcing ribs 14 and a ribbed reenforced cup bottom 15. A flared top 11 and a shoulder seat 12 facilitate the stacking of the pots together in the furnace.

1,686,087, October 2, 1928, Art of Refining Iron and Steel Products, Charles W. Hill, of Birmingham, Alabama.

This patent describes a process of refining iron which comprises storing the molten iron in a refiner 1 to approximately the level indicated at 22 and then passing combustion gases therethrough from the gas producer or furnace 2 through the pipes 3, 4 and 5. Means are provided for regulat-



ing the character of the gases discharged from the furnace 2 by means of the valves 10, 12, 13, 34 and the like, which control the amount of fuel and air going into the furnace 2 to produce gases which are either oxidizing or reducing with respect to the metal being treated. The gases are received in the refiner 1 or the pipe 5 at substantially the temperature existing in the furnace 2 and after passing through the bath 22, are discharged through the stack 36. When sufficiently refined, the metal is tapped from the spout 27.

1,676,856, Alloy, Alfred George Cooper Gwyer and Henry Wilfred Lewis Phillips, of London, England, Assignors to The British Aluminum Company, Limited, of London, England.

This patent describes the process of modifying aluminum-copper alloys in which the content of copper exceeds 6 per cent and in which a modifying element, such as calcium, in amounts of 0.3 per cent or less, is added to the

alloy at a temperature of 1470 degrees Fahr. (800 degrees Cent.) The addition of the calcium or other alkaline earth metal brings about a modification of grain structure and increase in tensile strength.

1,672,278, Metal Pot. Albert N. Otis, Schenectady, N. Y., assignor to General Electric Company.

The receptacle in this molten metal pot is divided into a number of chambers communicating with each other. An outlet duct extends downward into one of the chambers. The molten metal is forced out of the other chambers, into this chamber thus causing the metal to flow out through the duct.

1,686,223, October 2, 1928, Stable-Surface Iron-Chromium-Silicon Alloy, Percy A. E. Armstrong, of Loudonville, New York, Assignor to Ludlum Steel Company, of Watervliet, New York, a corporation of New Jersey.

This patent describes a stable surface iron-chromium-silicon alloy, particularly adapted for the production of rolled bars, sheets and the like. The carbon is preferably kept below 0.05 per cent, due to its detrimental influence on the stable surface qualities and workability of the material. The chromium content may vary from 13 to 30 per cent, preferably ranging from 16.5 to 18.5 per cent to secure the desired softness and workability with the requisite stable surface, and the silicon content is preferably from 0.5 to 5 per cent. The remainder is iron or small percentages of other metals. The alloy is produced by putting together degasified molten iron and pre-heated chrome alloy material, casting into ingots, hot working into reduced sizes, heating to an initial rolling temperature of about 1900 to 2300 degrees Fahr. and finishing rolling with substantially maximum draft roll passes, the rolling being completed at a temperature above 1100 degrees Fahr.

1,686,075, October 2, 1928, Process of Making Synthetic Pig Iron, Emil Edwin, of Trondhjem, Norway, Assignor to the Firm: Aktieselskapet, Norsk Staal (Elektrisk-Gas-Reduktion), of Oslo, Norway.

This patent describes a process of producing synthetic pig iron, of a quality comparable to Swedish charcoal pig iron, by reducing iron ore through reducing gases and magnetically separating the ore and gangue to produce sponge iron which is intimately mixed with pure carbonaceous material, such as charcoal, petroleum coke, or the like, and melted in an electric furnace under acid conditions and at as low a temperature as possible.

1,687,105, Recuperator-Type Oil Burner. George F. Naab, Lakewood, Ohio, assignor to The North American Manufacturing Company.

In this liquid fuel burner, high temperature air is passed through openings in a hollow body. The stem of an atomizing head extends in this hollow, the stem being tubular and having connection with a fuel supply at pressure greater than that of the air passing through the body and being arranged to convey the fuel to the head. The stem is cooled to prevent carbonization of fuel.

News of the Society

THE WESTERN METAL CONGRESS

THE week of January 14, 1929 will mark an epoch-making period in industrial California and the adjacent western states. As is already well known to all of our members this week will mark three important events —the Western Metal Congress, the Western States Metal and Machinery Exposition and the Semi-Annual Meeting of the A. S. S. T.

Papers of vast importance to industrial development will be read at sessions of the Western Metal Congress. Participating in these will be the American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, California Division of Development and Production Engineering of the American Petroleum Institute, American Welding Society, Society of Automotive Engineers, Pacific Coast Electrical Association, Pacific Coast Gas Association, Institute of Marine Engineers, Metal Trades and Manufacturers Association, Chamber of Mines and Oils, National Purchasing Agents Association and the American Society for Steel Treating.

The exposition which is to be held in the big Shrine Auditorium, will not be unlike that held in Philadelphia, October 8, during National Metal Week. Here will be shown the latest and finest equipment used in the metals industry. It will be representative of that industry which annually involves billions of dollars. Eminent scientists from all parts of America, and Europe will be in Los Angeles for the convention to absorb the latest technical information and to take back the results of these studies for introduction into their own business.

The rapid development of various industries in the western section of the country where the consumption of steel products has become so great and important makes the coming first Western Metal Congress and Exposition of exceptional importance to every part of the west.

Many advances in the study of steel have been made in the past year and these will be presented at the technical sessions.

Foremost in these advances is the perfection attained in the production of stainless steel. A complete discussion will be introduced of new alloys in the manufacture of corrosion-resisting steel and how it has improved the machining and grinding properties and reduced the tendency toward pitting and scratching.

The technical sessions during the convention will be the most important ever held in the West and will be of far reaching importance to all interested in the steel industry.

For those members who live in the eastern part of the country the Western Metal Congress presents another interesting angle and that is a winter vacation in the land of sunshine. It presents an opportunity to leave the land of ice and snow when winter is at its worst and enjoy a real vacation in the land of roses. An opportunity to go with a fine crowd of folks you know and like. An opportunity to visit your Western and Pacific Coast representatives and business connections—to size up the business possibilities out there at first hand—to open up new outlets for your business. In a word an opportunity to store up new health and energy through a needed midwinter vacation while you are gaining new ideas and impressions to help increase your business.

The Santa Fe Railroad is cooperating by running a special train from Chicago to Los Angeles, leaving Chicago the evening of January 7, 1929. Many have already indicated their intention to go to Los Angeles on the

special train. The arrangements provide for a 1-day stop-over at the Grand Canyon of the Colorado River.

The American Society for Steel Treating promises those who visit this Western Metal Congress a comfortable trip and an illuminating one from a scientific angle.

The Biltmore Hotel will be the headquarters for the American Society for Steel Treating. Make your reservations now, either directly with the hotel management or through the Society. Most important of all is that you be there. The complete program of technical papers will be published in January TRANSACTIONS.

Those Who Will Exhibit at Los Angeles

The following is a complete list of exhibitors as of November 15, 1928, of those companies and individuals who will have exhibits at the Western States Metal and Machinery Exposition at Los Angeles, California.

ABRASIVE COMPANY	Philadelphia
AHLBERG BEARING COMPANY OF CALIFORNIA	Los Angeles
AIR REDUCTION SALES COMPANY	New York
ALCORN COMBUSTION COMPANY	Philadelphia
AMERICAN BRASS COMPANY	Waterbury, Conn.
AMERICAN CAR AND FOUNDRY COMPANY	New York City
AMERICAN REFRACTORIES COMPANY	
ARMSTRONG-BLUM MANUFACTURING COMPANY	Chicago
ARMSTRONG BROTHERS TOOL COMPANY	Chicago
ATKINS AND COMPANY, E. C.	Indianapolis
ATLAS STEEL CORPORATION	Dunkirk, N. Y.
AXELSON MACHINE COMPANY	Los Angeles
BAUSCH AND LOMB OPTICAL COMPANY	Rochester, N. Y.
BELLIS HEAT TREATING COMPANY	Branford, Conn.
BETHLEHEM STEEL COMPANY	Bethlehem, Pa.
BLACK AND DECKER MANUFACTURING COMPANY	Towson, Md.
BOTFIELD REFRACTORIES COMPANY	Philadelphia
BRISTOL COMPANY	Waterbury, Conn.
BROWN INSTRUMENT COMPANY	Philadelphia
CALIFORNIA MALLEABLE CASTINGS COMPANY	Los Angeles
CARBORUNDUM COMPANY	Niagara Falls, N. Y.
CARBORUNDUM COMPANY	Perth Amboy, N. J.
CENTRAL ALLOY STEEL CORPORATION	Massillon, Ohio
CHICAGO STEEL AND WIRE COMPANY	Chicago
CLARK TRUCTRACTOR COMPANY	Battle Creek, Mich.
CLEVELAND TWIST DRILL COMPANY	Cleveland
COLONIAL STEEL COMPANY	Los Angeles
COOPER HEWITT ELECTRIC COMPANY	Hoboken, N. J.
CRUCIBLE STEEL COMPANY OF AMERICA	New York City
DEARBORN CHEMICAL COMPANY	Chicago
DISSTON AND SONS, HENRY	Philadelphia
DOHENEY STONE DRILLING COMPANY	Glendale, Calif.
DUCOMMUN CORPORATION	Los Angeles
EASTMAN KODAK COMPANY	Rochester
EX-CELL-O TOOL AND MANUFACTURING COMPANY	Detroit
FIRTH-STERLING STEEL COMPANY	Los Angeles
FORD COMPANY, J. B.	Wyandotte, Mich.
FUSION WELDING CORPORATION	Chicago
GAIRING TOOL COMPANY, INC.	Detroit
GATHMANN ENGINEERING COMPANY	Baltimore, Md.
GENERAL ELECTRIC COMPANY	Los Angeles
GLOBAR CORPORATION	Niagara Falls, N. Y.
GODDARD AND GODDARD COMPANY	Detroit

Halcomb Steel Company	Syracuse, N. Y.
Haynes Stellite Company	Kokomo, Ind.
Heppenstall Forge and Knife Company	Pittsburgh
Herberts Machine and Supply Company	Los Angeles
Houghton and Company, E. F.	Philadelpha
Hughes Tool Company	Los Angeles
Johnson Gear Company	Berkeley, Calif.
Jergensen Company, Earle M.	Los Angeles
Kay-Brunner Steel Casting Company	Los Angeles
Keese Engineering Corporation	Hollywood, Calif.
Kelly Reamer Company	Cleveland
Knapp Company, James H.	Los Angeles
L. A. Automotive Works	Los Angeles
Leeds and Northrup Company	Philadelphia
Leitz, Incorporated, E.	New York City
Linde Air Products Company	New York City
Ludlum Steel Company	Watervliet, N. Y.
Merco Nordstrom Valve Company	San Francisco
Machinists' Tool and Supply Company	Los Angeles
Morse Twist Drill and Machine Company	New Bedford, Mass.
National Twist Drill and Tool Company	Detroit
New Departure Manufacturing Company,	Bristol, Conn.
Norma-Hoffman Bearings Company	Stamford, Conn.
Northwestern Manufacturing Company	Milwaukee
Nuttall Company, R. D.	Pittsburgh
Pacific Abrasive Supply Company	Los Angeles
Pacific Factory	
Pangborn Corporation	Hagerstown, Md.
Penton Publishing Company	Cleveland
Plomb Tool Company	Los Angeles
Purox Company	Denver
Regan Forge and Engineering Company	San Pedro, Calif.
Simonds Saw and Steel Company	Los Angeles
Sleeper and Hartley, Inc.	Worcester, Mass.
Smith-Booth-Usher	Los Angeles
Snyder Foundry Supply Company	Los Angeles
Southern California Edison Company	Los Angeles
Southern California Iron and Steel	Los Angeles
Spencer Turbine Company	Hartford, Conn.
Spindler and Sauppe	San Francisco
Standard Oil Company	Los Angeles
Standard Tool Company	Cleveland
Steel Publications	Pittsburgh
Sterling Electric Motors Inc.	Los Angeles
Stoody Company	Whittier, Calif.
Strand and Company, N. A.	Chicago
Timken Steel and Tube Company	Canton, Ohio
U. S. Electrical Manufacturing Company	Los Angeles
Vanadium Corporation of American	New York City
Welding Engineer	Chicago
Western Drop Forge Company	Vernon, Calif.
Western Machinery World	San Francisco
Western Type and Steel Company	San Francisco
Westinghouse Electric and Manufacturing Co.	Pittsburgh
Whitman Barnes-Detroit Corporation	Detroit
Whitney Manufacturing Company	Hartford, Conn.
Wilcox Company, E. A.	Los Angeles
Wilson-Maeulen Company	New York City
Wisconsin Electric Company, Inc.	Racine, Wis.

ENGINEERING EXTENSION DIVISION

PROF. JOHN F. KELLER of the Engineering Extension Department of Purdue University is again with the Society for the fall months, as announced in an earlier issue of the TRANSACTIONS. He has successfully completed the first series of his six lecture course, "Steel and Its Treatment." The communities included are given below, together with the registration.

Springfield	215	Bridgeport	59
Hartford	187	Worcester	88
New Haven	77		
		Total	626

The response to this work has been most gratifying, and was due largely to the cooperation of Chapter officers, local chambers of commerce and a de-

Springfield Engineering Extension Class. The Largest Class yet Organized, An Enrollment of 215.

sire on the part of industries to spread the knowledge of iron and steel. This year each man received a copy of Professor Keller's book "Lectures on Steel and Its Treatment" which is the written record of his lectures.

The second series of lectures is being given in eastern Pennsylvania and New York.

ONTARIO CHAPTER

On Friday, October 26, at the Parkdale Canoe Club, E. R. Frost, president of the National Machinery Company, Tiffin, Ohio, spoke on the "Upset Method of Forging." There were 160 men who turned out to hear Mr. Frost and to see his motion pictures which showed upsetting operations in a remarkably clear manner.

The interest of this chapter was shown by the discussion that followed. Very accurate work can be done by this method, thus saving both time and labor.

At a luncheon meeting of the executive committee it was decided to change the name of the Toronto Chapter to the Ontario Chapter that all the industrial section of the province might be properly included in our chapter. This act

Ontario Chapter at Parkdale Canoe Club, Friday, October 26. There were 160 Men Present.

and proper by-laws to guard the interests of all communities were ratified by the evening meeting.

H. Kenneth Briggs, assistant national secretary, spoke on the work of the A. S. S. T. and aided in working out the details of the expansion of the chapter.

UNAUDITED FINANCIAL STATEMENT OF THE AMERICAN SOCIETY FOR STEEL TREATING

In connection with the statement published herewith, we wish to state that Messrs. Ernst & Ernst, Certified Public Accountants, have been employed and are auditing our records quarterly, and a certified Balance Sheet, together with a statement of Income and Expense, are to be submitted by them as of the close of business December 31, 1928, which will be published in TRANSACTIONS some time early in 1929.

UNAUDITED PROFIT AND LOSS STATEMENT AMERICAN SOCIETY *for* STEEL TREATING

For the period from January 1, 1928, to September 30, 1928

INCOME			
Membership Dues		$ 46,525.70	
Sustaining Exhibit Memberships		5,300.00	
Less		$ 51,825.70	
Apportionment of Dues to Chapters		19,904.52	$ 31,921.18
Transactions Advertising		$ 32,425.27	
Subscriptions		1,599.55	
Sales		681.76	
Reprints		970.67	
Bindery		1,092.25	36,769.50
Books			2,934.97
General Index			14.40
Data Sheets, Binders and Books			1,284.85
Data Sheet Book Advertising			7,025.00
Pencils, Pins and Buttons			64.12
Extension Division			6,255.00
Interest Earned			3,371.89
Interest Earned—Howe Medal Fund			61.99
Discount Earned			712.35
Sundry Income			68.15
1928 Convention Advance Receipts—Deferred	$59,829.90		
Western Metal Show Advance Receipts — Deferred	2,915.00		
TOTAL INCOME			$ 90,483.40

EXPENSE			
Support of Chapters		$ 651.08	
Transactions		32,996.75	
Reprints—Purchase for Resale		920.28	
Bindery—Purchase for Resale		1,448.28	
Books—For Library		358.11	
Books—Purchase for Resale		2,548.04	
John F. Keller Book		1,374.59	
Data Sheets, Binders and Books		10,906.47	
Pencils, Pins and Buttons—For Resale		59.79	
Extension Division		2,369.41	
Semi-Annual Meeting—Montreal		512.07	
Recommended Practice Committee		2,804.23	
Finance Committee		112.98	
Publications Committee		1,001.05	
Directors		2,012.23	
President's Office		241.87	
Treasurer's Office		4,271.54	
Secretary's Office		12,141.34	
General Expense		8,410.75	
1928 Convention Prepaid Expense—Deferred.	$25,326.75		
1928 Convention Prepaid Expense—Deferred.	555.16		
Western Metal Show Prepaid Expense — Deferred	2,985.21		
TOTAL EXPENSE		$ 85,140.86	
EXCESS INCOME OVER EXPENSE			$ 5,342.54

BALANCE SHEET as of September 30, 1928

ASSETS			
CASH			
Petty Cash Fund	$ 100.00		
Commercial Account	13,387.49		
Savings Accounts	29,664.56	$ 43,152.05	
SECURITIES			
U. S. Government Bonds	$ 28,000.00		
Other Securities	98,475.00		
Accrued Interest	82.99	126,557.99	
Accounts Receivable	$ 8,925.53		
Less—Allowance for Doubtful Accounts	924.65	8,000.88	
Inventory		4,535.70	
Travel Advances—Officers, Employees and Chapters		7,656.35	
Office Furniture and Fixtures		4,034.13	
Deferred Expense on Conventions		28,867.12	
TOTAL ASSETS			$222,804.22
LIABILITIES			
Apportionment of Dues to Chapters		$ 1,517.64	
Reserves		45,500.00	
Deferred Income on Conventions		62,744.90	
Surplus—January 1, 1928	$109,783.79		
Less—Adjustments for previous periods	2,084.65		
	$107,699.14		
Plus Excess over Expense during period from January 1 to September 30, 1928	5,342.54	113,041.68	
TOTAL LIABILITIES RESERVES AND SURPLUS			$222,804.22

VOLUME XIV COMPLETED

THIS issue of TRANSACTIONS completes Volume XIV, which covers the period from July, 1928, through December, 1928. Volume XV will include the period from January, 1929, through June, 1929. The index for Volume XIV is now ready for distribution and may be secured upon request.

Those desiring to have their loose copies of Volume XIV bound in accordance with the style used in binding Volumes I to XIII, inclusive, may do so by forwarding them to the executive office of the society, 7016 Euclid Avenue, Cleveland, together with $2.00 per volume, and they will be bound and returned promptly.

News of the Chapters

SCHEDULED MEETING NIGHTS OF CHAPTERS

For the convenience of visiting members, those chapters having scheduled meeting nights are listed below.

BOSTON—First Friday. H. E. Handy, secy., Saco-Lowell Shops, Lowell, Mass. Phone, Lowell 4050.

Dec. 7—Plant inspection, West Lynn Plant General Electric Co.
Duralumin and other Aluminum Alloys ..... H. C. Knerr
Motion Picture "Industrial Electric Heating"
Jan. 4—Nitralloy and the Nitriding Process ..... Dr. V. O. Homerberg
Motion Picture "Heat Treating with Gas."
Feb. 1—Manufacture and Heat Treatment of Springs ..... R. W. Cook
Mar. 1—Heat Treating Troubles ..... Jordan Korp
Apr. 5—Plant inspection, Fore River Yards, Bethlehem Shipbuilding Corporation, Quincy.
Welding ..... S. W. Miller
Motion Picture "Welding"
May 3—Annual Meeting
Quenching ..... F. R. Palmer

CHICAGO—Second Thursday. J. A. Comstock, secy., Peoples' Gas Light & Coke Co., Chicago.

Dec. 13—Heat Resisting Alloys ..... F. A. Fahrenwald
Jan. 10—Nitriding ..... V. O. Homerberg
Feb. 14—Drop Forgings ..... R. B. Schenck
Mar. 14—Machinability of Metals ..... A. H. d'Arcambal
Apr. 11—Theoretical Metallurgy ..... Zay Jeffries
May 9—Heat Treatment of Tools ..... J. F. Keller
June 8—Annual Picnic.

CLEVELAND—Third Monday. J. S. Ayling, secy., Case Hardening Service Company, Cleveland. Phone, Atlantic 0293.

Dec. 17—Forging ..... J. R. Adams
Jan. 21—Fuels and Furnaces ..... J. A. Doyle
Feb. 18—Chemistry of Steel ..... J. P. Gill
Mar. 18—Physical Metallography of Steel ..... Dr. Zay Jeffries

DAYTON—Third Monday. Fred M. Reiter, secy., Dayton Power and Light Co., Dayton, Ohio.

Dec. 17—Pyrometry and Automatic Temperature Control ..... C. S. Gordon
Jan. 21—Production Heat Treating ..... H. M. Spears
Feb. 18—Gray Cast Iron ..... J. W. Bolton
Mar. 18—Open for Requested Selection.
Apr. 15—Subject to be Selected ..... P. D. Merica
May 20—Program Entirely at Wright Field ..... J. B. Johnson
June Meeting—Annual Banquet.

DETROIT—J. G. Gagnon, secy., Hudson Motor Car Co., Detroit. Phone, Lennox 3232.

Dec. 17—Social Meeting.
Jan. 21—Fatigue of Metals ..... H. F. Moore
Feb. 18—Metal Stamping ..... Geo. Kelley
Mar. 18—Relation of Metallurgist to Management ..... C. F. Kettering
Apr. 14—Classification and Applications of Tool Steels .... To be announced
May —Ann Arbor Meeting, date, subject and speaker to be announced later.

GOLDEN GATE—Third Wednesday. H. E. Morse, secy., Morse Laboratories, San Francisco.

Dec. 12—Welding and Welded Sections.

Jan. 16—Meeting left open in order to arrange program for National Society members from Convention.
Feb. 20—Corrosion and Corrosion Resisting Materials.
Mar. 20—Aircraft Materials.
Apr. 17—Heat-Treating Steel and Cast Iron Castings.
May 15—Structural and Railroad Steels.
June 19—Pyrometry.

HARTFORD—Second Tuesday, with the exception of January 15. H. I. Moore, secy., Firth Sterling Steel Co. Phone, 6-5554 Hartford.

Dec. 11—Cast Iron .....P. W. Blackwood
Jan. 15—Some Present Trends in Engineering Steels .....C. E. MacQuigg
Feb. 12—Electric Heat in Industry Motion Picture .....Lewis Knapp
Mar. 12—Bronze Bearing Metals and Their Heat Treatment ..C. H. Bierbaum
Apr. 9—Globar Heating Elements and Their Application to Heat Treating Furnaces .....Arnold Pfau
May 14—Nitralloy and the Nitriding Process .....V. O. Homerberg
June 11—Tenth Annual Banquet.

INDIANAPOLIS—Second Monday. N. R. Gorsuch, secy., Citizens' Gas Co., Indianapolis.

Dec. 10—Steel Failures and How to Produce Them .....H. B. Knowlton
Jan. 14—Fatigue of Metals .....H. F. Moore
Feb. 11—Ask Me Another; Speakers—All Those with a Question or an Answer.
Mar. 11—Manganese Steels .....J. H. Hall
Apr. 8—Indiana Meeting.
May 13—Aircraft Metallurgy .....J. B. Johnson
June 1—Second Annual June Frolic.

MONTREAL—D. G. MacInnes, secy., 377 Claremont Ave., Westmount, Montreal.

Dec. 1—Smoker and Entertainment
Jan. 14—Corrosion of Steel .....F. N. Speller
Feb. 11—Manufacture of High Strength Iron .....R. C. Gray
Mar. 11—Modern Developments in Locomotive Forgings .....L. H. Fry
Apr. 8—Centrifugal Pipe in Sand Molds .....J. T. MacKenzie

NEW HAVEN—Third Thursday, with the exception of November 22 and May 23. F. E. Stockwell, secy., Standard Oil Co. of New York. Phone, Beacon 1520, Pioneer 9940.

Dec. 20—Jewels of Industry—Moving Picture.
Jan. 27—Stainless Iron .....N. L. Mochel
Feb. 21—Nickel Chromium Alloys in Gray Iron .....D. M. Houston
Mar. 21—Chromium Plating .....William Blum
Apr. 18—Non-Ferrous Metals .....Arthur Phillips
May 23—Subject to be announced later .....A. Cook
June —Annual Outing.

NEW YORK—T. N. Holden, Jr., E. W. Bliss Co., New York City. Phone, Sunset 9000.

Dec. 10—The Early History of Chromium Steel and Ferrochromium..... three speakers closely associated with the developments.
Jan. 14—No definite subject, meeting planned especially for New Jersey members .....B. F. Shepherd
Feb. 18—Use of Steel in Subway Construction .....J. R. Slattery

NOTRE DAME—Second Thursday. C. E. McDermott, secy., 511 E. Howard St., South Bend, Ind.

PITTSBURGH—First Thursday. H. L. Walker, secy., 414 Tripoli, Pittsburgh, North Side Station.

WASHINGTON-BALTIMORE—Third Friday. J. E. Crown, secy., 727 Fifth St., Washington.

December—The Age of Speed, movie and lecture.....Norton Company
January —Steel Castings .....R. A. Bull
February —Recent Developments in Copper Alloys.....W. H. Bassett
March —Corrosion of Metals .....U. R. Evans
(Three lectures—joint meeting with several other scientific societies in Washington)

April —Metallurgical Applications of Vanadium .....Jerome Strauss
May —Open

WORCESTER—C. G. Johnson, secy., Worcester Polytechnic Institute. Phone, P110.

Dec. 13—Ball Bearing Steels .....F. G. Hughes
January Meeting—Mechanical Working of Steel .....A. W. F. Green
February Meeting—Practical Heat Treating Troubles.....W. S. Bidle
March Meeting—Plating of Metals—Speaker to be announced later.
April Meeting—Questions—Speaker to be announced later.
May Meeting—Subject and speaker to be announced later.

STANDING OF THE CHAPTERS

DURING the month of October there were 270 new and reinstated members, while 144 were lost through non-payment of dues and 10 through resignations and deaths, leaving a net gain of 116 members for the month.

The total membership of the society on November 1, 1928, was 5,005.

GROUP I		GROUP II		GROUP III	
1. Detroit	489	1. Los Angeles	170	1 New Haven	100
2. Chicago	438	2. Hartford	146	2. Tri-City	92
3. Pittsburgh	372	3. Golden Gate	126	3. Worcester	72
4. New York	322	4. Lehigh Valley	120	3. Washington	72
5. Philadelphia	321	5. Milwaukee	117	4. Ontario	69
6. Cleveland	299	6. Cincinnati	107	5. Rockford	65
7. Boston	256	7. St. Louis	102	6. Rochester	59
		8. Dayton	100	7. Providence	58
		9. Indianapolis	95	8. Columbus	48
		10. Canton-Mass.	89	9. Southern Tier	47
		11. Syracuse	85	10. Schenectady	46
		12. Buffalo	84	11. Springfield	36
		13. Montreal	71	11. Notre Dame	36
		14. North-West	56	12. Fort Wayne	27

GROUP I—All the chapters in Group I remain in the same position they held last month; however, they all had gains, Detroit having the largest with eleven and Pittsburgh and Boston with nine each.

GROUP II—Los Angeles, while holding first place, also leads its group in increase of membership, having added nine to its rolls for the month. The tie between sixth and seventh positions last month was broken by Cincinnati's gain of three and St. Louis' loss of two, Cincinnati gaining sixth place. Syracuse with a gain of five exchanged places with Buffalo, who goes into twelfth place. Three chapters in this group suffered losses, while the others all made additions to their rosters.

GROUP III—Worcester and Washington, each losing two members, are still tied for third and fourth places. Toronto Chapter, on becoming the Ontario Chapter, added sixteen names to its membership, goes into fifth position, displacing Rockford, Rochester and Providence in one step. This chapter is due to come up higher, so those just ahead of it should take heed. We are pleased with the showing of the Notre Dame Group, which increased its rolls by thirteen, resulting in a tie with Springfield.

BOSTON CHAPTER

The November meeting of the Boston Chapter was held at Massachusetts Institute of Technology, Cambridge, on Friday, November 9, 1928. Dinner was served in Walker Memorial at 6:30 p.m. and was attended by more than 75 members and guests. An invitation had been sent to all members of the New England Foundrymen's Association and many of them were present at both the dinner and the evening meeting.

The guest speaker of the evening was Dr. W. H. Hatfield, director of the Brown-Firth Research Laboratories, Sheffield, England, whose subject was "Cast Iron." He was introduced by Prof. G. B. Waterhouse with whom he had attended Sheffield University, and with whom he has been in intimate touch over a long period of years.

Dr. Hatfield spoke in general on the modern developments in cast iron manufacture, such as pearlitic iron, the advantage of co-operative research associations, the manufacture of the lower carbon high test cast irons and the use of alloys in the production of better castings. The talk was followed by a long discussion which lay chiefly along the lines of a comparison between methods of manufacture and tests in England and the United States. This discussion was led by Dr. Waterhouse and among those taking part were Dr. Albert Sauveur, of Harvard University; F. F. Harrington, of Hunt Spiller Mfg. Corp., a former president of the New England Foundrymen's Association; and J. S. Vannick, development engineer of the International Nickel Company, all of whom discussed principally the effect of nickel and chromium in cast iron as regards physical properties and machinability. At the conclusion of the discussion a rising vote of thanks was tendered to Dr. Hatfield for a most enjoyable eveing and most of the two hundred present remained to meet the Doctor personally.

During his stay in Boston Dr. Hatfield presented two lectures before the students of M. I. T., many of the members of the Boston Chapter accepting the invitation of Dr. Waterhouse to attend. These lectures, "The Application of Science to the Steel Industry" and "Acid and Rust Resisting Steels" were fully illustrated and greatly enjoyed by those able to attend.

Howard E. Handy

CHICAGO CHAPTER

The second meeting of the year for the Chicago Chapter was held October 4, at the City Club. An innovation in chapter history was inaugurated, and the ladies were invited to see what a steel treaters' meeting was like. The response was good, and about a hundred and fifty, including the ladies, were present. A steak dinner was the important leader in the sequence of events, eaten to the tune of a screened string orchestra, and seemingly enjoyed by all.

After the chairman, A. M. Steever, had welcomed the ladies, founder member T. E. Barker arose and gave a brief eulogy of founder member Arthur G. Henry, who had so suddenly passed away just one year previously. The whole chapter then stood in silence for a moment with bowed heads in memory of the man who had done so much for the A. S. S. T., both locally

and nationally. He now lies in his old home town in Wisconsin; under a monument erected by the Chicago chapter and his A. S. S. T. friends bearing a bronze tablet which tells of the love and honor in which the Society holds his memory. This information, together with a statement to the effect that the Chicago Chapter has guaranteed perpetual care to this last resting place, was given by W. R. Mau, who headed the committee which made these arrangements.

After an announcement by the secretary, J. A. Comstock, of the special train to Philadelphia for Chicagoans and neighboring society members, the chairman called on the visiting chairman of St. Louis Chapter, W. E. Remmers. Mr. Remmers gave an invitation to visit his chapter to anyone who was likely to be in St. Louis on meeting night.

The address of the evening was one in which technical interest was combined with general interest, particularly to the ladies. Robert S. Archer, metallurgist of the Aluminum Company of America, was the speaker, and his subject was a broad one, "After The Iron Age Comes Aluminum." Mr. Archer outlined the short history of this important metal, and then told of the present processes of manufacture, mentioning the mammoth million horsepower plant now operating in Quebec. He then spoke of the present commercial grades of aluminum and mentioned its principal uses. A moving picture of the manufacture of aluminum cooking utensils, of particular interest to the ladies, was presented, and Mr. Archer then closed with a description of the principal metallurgical and engineering features of his subject. He displayed samples illustrating different processes of manufacture, including rolled and extruded products, forgings, and sand, permanent mold, and die-cast parts. His talk was so complete, and the ground was covered so thoroughly, that there was not much left to be discussed, and the discussion was brief. The meeting closed with a rising vote of thanks to the speaker for an able talk, well presented. *D. L. Colwell.*

GOLDEN GATE CHAPTER

The October meeting of the Golden Gate Chapter was held on the evening of October 10, 1928, at the plant of the Hall-Scott Motor Car Co., division of American Car and Foundry Motors Co., Berkeley, California. The meeting was preceded by a dinner served in the factory cafeteria.

The Hall-Scott Motor Car Co. had prepared a most interesting program and plant visit, which was thoroughly appreciated by the large number present. After the dinner the meeting was called to order by Mr. Edwards, chairman of the program committee, who introduced C. L. Warwick, secretary of the American Society for Testing Materials, who was our guest for the evening. Mr. Warwick delivered an interesting talk outlining the work and aims of his society. He explained the relationship between his society and ours, and the cooperation which has produced the standards and recommended practices which have been published. Inasmuch as this was Mr. Warwick's first visit to the Pacific Coast, we were much pleased to have been able to meet him in this way.

The meeting was next broken up into small parties, each one led by a

guide, who took us through the plant, which was in operation. The inspection was very interesting and thorough.

We then returned in order to hold the meeting proper, which was called to order by Dr. Cook. P. P. Mapes, in charge of the metallurgical inspection at the plant, delivered an interesting address on his methods, which was followed by an inspection of his testing laboratory.

H. E. Morse.

LEHIGH VALLEY CHAPTER

The October meeting of the Lehigh Valley Chapter was held at the Exhibit Building of the Bethlehem Steel Co. on Friday evening, October 5. The occasion was marked by a thoroughly enjoyable and instructive illustrated talk by Dr. C. H. Herty, Jr., supervising metallurgist, Bureau of Mines, Pittsburgh.

While the subject of Dr. Herty's talk was "The Manufacture of Alloy Steels in the Open-Hearth Furnace," Dr. Herty not only covered this subject, but gave also a very illuminating discourse on slag and metal reactions in the basic open-hearth furnace and their effect upon the quality of the finished steel. In this connection Dr. Herty pointed out that the three important factors in the production of clean steel are proper slag viscosity, low oxide content in the slag at the time of tapping, and a brisk boil during the working of the heat. Many of the details of Dr. Herty's talk are covered in recent papers read before the society, representing several years of very valuable work conducted under his supervision at the Bureau of Mines. The talk was followed by a lively and gratifying discussion of the various points touched upon by Dr. Herty in his lecture. The Chapter feels very fortunate in having had a session of this nature, so filled with valuable information, and looks forward to a number of equally practical talks during the present season. *J. E. Killmer.*

MILWAUKEE CHAPTER

The October meeting of the Chapter was featured by a very interesting talk by Dr. F. B. Coyle of the International Nickel Co. on the "Use and Effects of Nickel and Chromium in Cast Iron."

Due to the appeal of this subject matter to foundry men in general, the members of the Gray Iron Research Group and the University of Wisconsin were invited to attend and were present in good number.

After the dinner, which was unusually well attended, Dr. Coyle began his lecture which was accompanied by a number of slides showing the effects of various percentages of nickel and chromium and combinations of both on cast iron. The meeting was then open for discussion and quite a number of comments were brought forth from members of this audience who were interested in alloy cast iron and had some experience in the use of it.

The meeting then adjourned with a rising vote of thanks to the speaker. *L. J. Radermacher.*

NEW HAVEN CHAPTER

The second meeting of the New Haven Chapter was held at the Heppenstall Forge Co., Bridgeport, on Thursday, October 18, at 6 P. M. Forty members and guests enjoyed a very fine buffet lunch supplied by the above company. Included in the menu were clam chowder, liver and bacon sandwiches, steak sandwiches, potato salad, coffee and ice cream.

Having finished the dinner the members were taken for a trip through the forge shop and heat treating department. The most fascinating sight was the forging of die blocks under the large hydraulic press. These die blocks, the average weight of which is about 1200 pounds, were upset on all six sides and handled very easily by a manipulator. This machine has two arms, is operated by one man, and is almost human. The one remarkable feature is that it takes but two men to transform a rough block of high grade alloy steel into a finished die block in such remarkable time, about 7 minutes.

The heat treating department was next visited. It is one of the most modern in the country for the heat treatment of large and small forgings. The large car type oil burning furnaces are equipped with electrically controlled valves and recording instruments. A uniform temperature is very easily maintained throughout the entire furnace. The oil quenching system is also very unique in its cooling properties and a very uniformly hardened product is obtained.

The meeting was opened by Chairman Fish at 8 P. M. There were 58 members and guests present. Paul Eddy, our past chairman and representative to the annual convention, gave a report of the membership and financial condition of the National Society.

Horace W. Staples, metallurgist of the Bristol Brass Co. gave a very interesting talk on the "Uses and Applications of Copper and Copper Alloys." The subject was very well received and a lively discussion followed. It is hoped that Mr. Staples will address us again in the near future.

It is very encouraging to see the spirit which is shown by the members in attending the meetings which are held in three cities, New Haven, Waterbury and Bridgeport. The following cities were represented:

Bridgeport	28	Wallingford	5
New Haven	10	Waterbury	4
Ansonia	4	Seymour	2
Hartford	2	Derby	1
Milford	1	Bristol	1

The attendance prize, a pair of gloves, presented by Chairman Fish of the Ready Tool Co., was won by Irving Mitchell of the R. Wallace & Co., Wallingford. We are very glad to welcome a new member, Frank Quinlan, engineer of tests of the New York, New Haven and Hartford Railroad.

Our next meeting will be held in the auditorium of the Chase Metal Goods Co., Waterbury. Jordan Korp, service engineer of the Leeds and

Northrup Co., will talk on the "Procedure of Correct Hardening."

So, on to Waterbury. *R. T. Porter.*

ONTARIO CHAPTER

The Ontario Chapter is the new name of the Toronto Chapter, expanded to include the territory around Hamilton, Brantford, Galt, Guelf, Kitchener and Welland, Ontario. For a long time there has been a growing demand for a Group in this territory both from the scattered body of members residing therein, and from the industries of that section.

The prime movers met together at the Philadelphia Convention and felt that this consolidation was desirable. The details were worked out and the consolidation ratified by a meeting at the Parkdale Canoe Club, Toronto, on October 26.

A set of by-laws guards the interests of all communities and insures half the meetings in the new territory centering at Hamilton and half at Toronto. Representation on the executive committee is to be in proportion to the number of members in each community. The new territory is represented by Hugh F. Davis, International Harvester Company, Hamilton and Bruce Donald, Verity Works, Massey-Harris Company, Brantford and four others to be selected in the immediate future.

Best wishes of the society go to the Ontario Chapter.

PHILADELPHIA CHAPTER

The co-operative course in heat treatment and metallography of steel, given at Temple University under the auspices of the Philadelphia Chapter, held its first meeting of the current school year on October 15.

The first year students, taking the full course including one lecture hour and three laboratory hours per week, number sixty-five; four men are taking the lectures only, and ten former students have enrolled for the advanced course, for the solution of practical heat treating and metallurgical problems.

Temple University's exhibit at the National Metal Exposition was an important factor in the unusually large enrollment this year. The exhibit attractively displayed the benefits to be derived from taking the course and showed some results secured by former students in reducing production costs and increasing service from heat treated parts. The walls of the booth were decorated with photographs taken in the metallurgical laboratory and of other points of interest about the University. A most artistically illuminated model of the new Temple University created a great deal of interest. The new University is now under construction, and when finished will provide a modern laboratory well fitted to house the complete and excellent equipment now owned by the course.

Two members of the metallurgy class alumni association were in attendance at the booth each day, to receive inquiries and furnish information relative to the course and the University. The alumni also turned out to assist in the laboratory, during the inspection trip arranged to afford the visiting delegates an opportunity to see Temple.

Horace C. Knerr, director of the course, and his associates were voted an expression of appreciation by the Philadelphia Chapter for this constructive educational work, which was partly responsible for the award to the chapter, of the bell and gavel, for the year 1928-1929.

A. M. Lindsley.

PITTSBURGH CHAPTER

The Pittsburgh Chapter held its November meeting on the evening of the first at the U. S. Bureau of Mines Building.

Chairman McInerney called the meeting to order and, after conducting a short business session, welcomed Marcus Grossmann, metallurgist of the Central Alloy Steel Company of Canton, Ohio, as the speaker of the evening.

Mr. Grossmann introduced his subject, "Chrome-Iron and Related Alloys," with a few preliminary remarks and then proceeded to give a most comprehensive outline of the making, heat treating and fabricating of this material. He pointed out some of the earlier difficulties experienced and later overcome in fabricating chrome-iron for certain commercial uses. Among the commercial uses to which it had been put, he showed samples of tubing, plates, rivets, wire screen and cooking utensils.

He pointed out the general types of chrome-iron and explained their position and heat treatment characteristics in the iron-chromium diagram at elevated temperatures.

When Mr. Grossmann had concluded his talk, an exceptionally lengthy and general discussion took place which was only ended by the lateness of the hour. The appreciation of the chapter was extended to Mr. Grossmann by a hearty applause at the adjournment.

The chapter was glad to be visited by James O. Handy of the Pittsburgh Testing Laboratory who now resides in the New York district.

John A. Succop, chairman of the chapter's meetings and papers committee, extended a much appreciated invitation to the chapter in behalf of the Heppenstall Forge and Knife Company to attend a demonstration on Friday afternoon, Nov. 16, of two 600-pound capacity Ajax Northrup Induction Type Furnaces which have recently been installed in this company's plant.

The December meeting of the Pittsburgh Chapter will be a social affair at the Faculty Club to which the members will bring guests and the evening will be given over to various entertainment features.

There was no regular October meeting held by the Pittsburgh Chapter as the members were invited to attend the three lectures given by Dr. W. H. Hatfield at the Carnegie Institute of Technology on the evenings of October 16, 17 and 18. *Harry A. Neeb, Jr.*

ROCHESTER CHAPTER

The first meeting of the Rochester Chapter was held at the Hotel Osburn, September 10, preceded by a dinner, which was well attended by members and guests.

After the dinner, the chairman, C. F. Wattel, called the meeting to order, and after a short business session the speaker, Owen K. Parmiter, metallurgical engineer of the Firth-Sterling Steel Co., was introduced who presented a most interesting paper dealing with "Chromium Steels."

Mr. Parmiter began his talk by stating that there have been many new high chromium steels put on the market in the present century, but the two outstanding classes are a high tungsten group of which the modern high speed steel is representative, and the other a high chromium group which includes numerous varieties of steel. The author discussed in detail the various types of chromium steels of the tool steel type, the structural type and the stainless type. His paper was very interesting and considerable interesting and valuable discussion followed. A rising vote of thanks was extended to Mr. Parmiter. *H. J. LeClaire*

On September 29 thirty-five members and guests of the Rochester Chapter enjoyed an inspection trip to the Atlas Steel Corp. at Dunkirk, N. Y. The trip was arranged by the Educational Tours Committee of which R. H. Morris is chairman.

The group left the Hotel Osburn at 7:30 a.m., arriving at the White Inn, Freedonia, N. Y., at 11:30 a.m., when the group were luncheon guests of the Atlas Steel Corp.

After a brief talk by Mr. Lounsberry, vice-president of the company, "On what we would see at the mills," all proceeded to that point. Members and guests were divided into groups with well informed guides, and a thorough inspection of the mill followed, including the melting, pouring, rolling, forging, laboratories, store rooms, inspection, grinding, heat treating, and many other things of interest.

All who took this trip felt that the hours spent at the mills of the Atlas Co. had been well worth the time and appreciated the courtesy of the officers and employees of the above company. *H. J. LeClaire*

ROCKFORD CHAPTER

The second meeting of the season was held Tuesday, October 23, in the Venetian Room of the Nelson Hotel. Forty members and guests attended the 7 o'clock dinner which preceded the meeting.

Chairman R. M. Smith opened the business meeting at 8 p. m. and the minutes of the previous meeting were read and approved.

Swan Hillman, Rockford Chapter's delegate to the recent Convention in Philadelphia. read his report, which was one of the most interesting and thorough reports ever presented by a delegate. Election of officers, papers presented, plant visitation, social activities, etc., were included in the report.

The speaker of the evening was F. B. Coyle of the International Nickel Company of Bayonne, N. J., who spoke on "Nickel and Chromium in Grey Cast Iron." Mr. Coyle gave a very good talk, which was illustrated with lantern slides, showing effect of nickel and chromium in iron on various articles, such as cams on tractors, automobile parts; tensile strength of arbitration bars, etc. Following his talk a very interesting discussion took place.

The meeting adjourned at 10:00 p. m. with a rising vote of thanks to the speaker. *George R. Monks.*

ST. LOUIS CHAPTER

The regular meeting of the St. Louis Chapter was held Friday evening, Oct. 19, at the American Annex Hotel.

The meeting was preceded by the usual fine dinner after which the meeting was called to order by our chairman, W. D. Thompson, and the minutes of the previous meeting were read and approved. A few short talks by the various members who were at the national convention at Philadelphia, of experiences they had while at the convention, were given. At this time Prof. George L. Clark, professor of chemistry, University of Illinois, consulting director, Industrial X-ray Research Laboratories of St. Louis, gave a paper on the "Service of X-rays in Steel Treating and Other Industrial Processes."

Dr. Clark gave a general account illustrated with numerous lantern slides showing the astonishing new applications, achievements and possibilities of the X-ray diagnosis, research and testing of industrial materials with special reference to the control of mechanical and heat treatment of metals and alloys. His lecture was based on researches at the Massachusetts Institute of Technology and the University of Illinois, which has resulted in the establishment of a laboratory, the first of its kind in the United States, devoted entirely to the application of X-ray diffraction methods and the problems of industry of today. Questions were asked and answered very ably by Dr. Clark. We might add at this time that the Industrial Research Laboratories located in the Dick X-Ray Company Building, 3974 Olive St., St. Louis, extend a cordial invitation to visit the laboratories at any time.

The meeting was adjourned with a rising vote of thanks to Dr. Clark for his modern and instructive talk. *Carl G. Werscheid.*

WASHINGTON-BALTIMORE CHAPTER

The first meeting of the current season was held Monday, October 8, in the auditorium of the Interior Department Building. The usual dinner was held at the Cosmos Club and was well attended.

For the speaker of the evening, the Washington chapter was very fortunate to secure Dr. W. H. Hatfield, who for many years has been associated with the Brown-Firth Research Laboratories, England. Dr. Hatfield's subject was, "The Application of Science to the Steel Industry."

The effects of design of molds upon the characteristics of the interior of ingots were discussed and many interesting slides were shown. The casting temperature was stressed as of much importance, as the structure can be made all fine grained if the casting temperature and rate of pouring are right. Creep in engineering materials at elevated temperatures was discussed and for the information of the designer, Dr. Hatfield advocates the time yield method. This consists in discovering by static loading, the stress within which, at the temperature, stability of dimensions is attained within a period of 24-hours, for a further period of 48-hours with an extension not exceeding the elastic deformation by 0.5 per cent on the gage length. The limitation as regards measurement for permanence of dimensions is 0.01 per cent of the gage length.

A lively discussion followed Dr. Hatfield's paper. *W. R. Angell.*

WORCESTER CHAPTER

V. P. Malcomb, metallurgical engineer of the Chapman Valve Co., Indian Orchard, Mass., was the principal speaker at the second regular meeting of the Worcester Chapter held on Tuesday, Oct. 16. Mr. Malcomb's subject was "Castings" and his talk was very well received, making a "big hit" with all who were present. The following is a brief resume of Mr. Malcomb's talk:

To make good, clean, sound castings requires standardization to the highest degree of all factors contributing to the manufacture of casting and continual research into details that influence each operation. These conditions of manufacture can only be obtained by large foundries and because they are so necessary to good casting it is difficult to see how small foundries can exist, knowing that they cannot maintain the departments necessary for proper standardization and research.

Many foundries, large and small, are turning out castings that are ruining the reputation of castings and compelling people to use forgings for greater strength. But the trouble is that forgings have the same defects that are apparent in castings and, like castings, can be unsound and nonuniform. Castings can be made that compare favorably to forgings of similar design, but to make such castings requires the best of effort in all the operations. It is important to remember to get castings of strength comparable to forgings often requires the best of heat treatment after casting.

Foundries are today trying to turn out castings that will give them a good reputation for quality.

Mr. Malcomb showed a number of pictures of methods in use in his foundry and also of castings that were bad, explaining their defectiveness. X-rays have played an important part in the investigation of defective castings but Mr. Malcomb proved that they are not conclusive in their report, and at best, in the hands of a well trained man, they are only a good tool and have their limitations.

One of the important developments is that of a physical test of the pig iron. Mr. Malcomb has found that although the chemical test shows pig iron the same, a physical test will show a marked difference. When pig iron does not meet their physical test it is rejected as they have found that such pig iron will make defective casting no matter what type of practice is used in molding, melting and casting.

Sand should receive a lot of attention and it is necessary to keep a constant check on its quality. The handling of the sand is quite a problem in itself. The sand should not be allowed to be mixed by the molders, because no two molders will get the same mixture. This should all be taken care of at night and mixed to pass a standard test and when the molder comes to work in the morning his sand is all ready for him and he is not allowed to change its condition. The reclaiming of sand is at present a serious problem in most foundries.

Mr. Malcomb's talk covered a great many equally as interesting points in making good castings and all who were present at this meeting feel as though they now can appreciate better the difficulty encountered by foundries in their attempt to make better castings. It requires the co-operation of everyone that influences the manufacture of castings and Mr. Malcomb said that this spirit is becoming more apparent throughout the casting industry.

Carl G. Johnson.

Items of Interest

J. J. CURRAN, formerly metallurgist with the Henry Souther Engineering Co., Hartford, Conn., is now with the Harrisburg Pipe Bending and Machine Co., Harrisburgh, Pa.

R. M. Sandberg has been appointed general manager of the Columbia Tool Steel Co., Chicago Heights, Ill. Mr. Sandberg has been associated with the Columbia Tool Steel Co., in various capacities, for sixteen years.

Eugene Bouton, supervisor of time study for the Chandler-Cleveland Motors Corp., has recently resigned his position and will now be connected with the J. I. Case Threshing Machine Co., Racine, Wis.

Charles Pack has resigned as first vice-president and assistant general manager of the Doehler Die-Casting Co., and announces the establishment of a consulting office in the Woolworth Bldg., New York.

The L. J. Wing Mfg. Co., 154 W. 14th St., New York, has recently published a booklet entitled "Improved Gas Producer Operation." This booklet describes the Wing turbine blower and may be obtained by addressing a request to the above company.

E. F. Houghton and Co., Philadelphia, has issued two booklets, "Houghto-Clean for the Metal Industries," describing the use of this product for cleaning metal products, and "Hocut," which covers this transparent, water-soluble, metal cutting coolant. These booklets may be obtained from E. F. Houghton Co., on request.

A discussion of time control in heat treatment where distortion is detrimental is given in bulletin No. 2808, issued by Stanley P. Rockwell Co., Hartford, Conn.

"The Story of Newton Steel" is the title of a booklet recently issued by the Newton Steel Co., Youngstown, O., manufacturers of sheet steel for various purposes.

Research Paper No. 25, entitled, "A Study of the Hydrogen-Antimony-Tin Method for the Determination of Oxygen in Cast Irons," and Research Paper No. 26, entitled, "Note on the Effect of Repeated Stresses on the Magnetic Properties of Steel," are available from the Government Printing Office, Washington. The price is 5 cents each.

The Marshall Blow Pipe Co., 7431 Dubois St., Detroit, has recently developed an automatic continuous vertical forging machine. It is stated

that the furnace operates automatically, handling continuously such unwieldy parts as automobile rear axle housings and positively limits the application of heat to the area desired.

Petty and Wherry, Inc., 50 Church St., New York City, have been appointed metropolitan distributors for the Buckwall Engineering Co., Brooklyn, N. Y.

Pot type electric furnaces for lead, salt and cyanide baths for temperatures up to 1650 degrees Fahr., are described in a folder distributed by the American Metallurgical Corp., Boston.

"Malleable Foundry Refractories" is the title of a pamphlet issued by the U. S. Department of Commerce, Bureau of Standards. This covers simplified practice recommendations for the elimination of waste through simplified commercial practice. This booklet may be obtained from the U. S. Government Printing Office, Washington. The price is 10 cents.

Leeds and Northrup Co., Philadelphia, has available for distribution bulletin No. 500, entitled, "Automatic Control of Acid Baths."

The Automatic Temperature Control Co., Philadelphia, announces that its Cleveland district office is now located at 5005 Euclid Ave.

Bulletin No. 100 covering a pocket radiation pyrometer for high temperature service has been issued by the Colonial Supply Co., 217 Water St., Pittsburgh.

A recent report issued by the commercial standards group of the department of commerce states that earlier attempts to establish standards for tool steels resulted in failure because of the unwillingness of manufacturers to submerge the individuality of their various brands. More recently a committee of the American Society for Testing Materials has made a more successful attempt to establish for tool steels some standards that do not prescribe the details of elements as do standard specifications for other steels.

At a recent meeting of the metallurgical advisory board to the Carnegie Institute of Technology and the U. S. Bureau of Mines in Pittsburgh announcement was made that the following published reports are now available for distribution: Bulletin 36. "Deoxidation with Silicon and the Formation of Ferrous-Silicate Inclusions in Steel," by C. H. Herty, Jr., physical chemist, U. S. Bureau of Mines, and G. R. Fitterer, research fellow, Carnegie Institute of Technology, and junior metallurgist, U. S. Bureau of Mines—1928, 94 pages and 27 illustrations, Price $1. Bulletin 37. "A Study of the Dickenson Method for the Determination of Nonmetallic Inclusions in Steel," by C. H. Herty, Jr., physical chemist, and G. R. Fitterer, junior metallurgist, U. S. Bureau of Mines, and J. F. Eckel, research fellow, Carnegie Institute of Technology—1928, 27 pages and 4 illustrations, Price 50 cents.

(Continued on Page 36 Adv. Sec.)

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The Inland Steel Co., Chicago, has distributed an illustrated booklet on Inland copper-alloy steel sheets. This includes data on tests conducted by a committee of the American Society for Testing Materials.

Acid bulletin No. 1 of the American Manganese Bronze Co., Philadelphia, describes various types of metals which resist the action of sulphuric acid.

The Moltrup Steel Products Co., Beaver Falls, Pa., has issued a 100-page catalog on cold-drawn and miscellaneous steel products. This catalog describes a wide variety of steel sections produced by the company, including a number of alloy steels.

Improved methods of manufacture by the use of Hardtem die blocks are discussed in a recent folder issued by the Heppenstall Forge and Knife Co., Pittsburgh.

A 32-page booklet describing 25 different classes of furnaces, ovens and melting pots used in the manufacture of electrical equipment, has been issued by the General Electric Co., Schenectady, N. Y. All of these devices use current for the heating medium, the largest one described is a car-type annealing furnace, the smallest is a glue pot.

The claims for Carboloy as a material for metal cutting tools are set forth in a booklet issued by the Carboloy Co., Inc., New York.

The Bristol Co., Waterbury, Conn., has issued a catalog describing and illustrating equipment for centralized control with electrical transmitting and recording equipment.

Announcement has recently been made of the organization of the Krupp Nirosta Co., Inc. It is stated that the purpose of the organization is for pooling alloy steel patents belonging to the Krupp Steel Works of Germany and the Ludlum Steel Co., Watervliet, N. Y. It is also stated that the Central Alloy Steel Corp., and the Firth-Sterling Steel Co. are interested in the agreement as licensees for the use of the patents.

Another recent report states that representatives of the Krupp Co., and the General Electric Co. have made arrangements whereby a new cutting material, which has a cutting capacity far in excess of any high speed steel, will soon be put on the market. Basic patents on this material were held by the General Electric and Krupps.

The fourth annual conference on welding will be held at Purdue University, Lafayette, Ind., Dec. 12 to 14. This conference is under the direction of the engineering extension department and the department of practical mechanics, with the school of chemical engineering and manufacturers of welding equipment co-operating.

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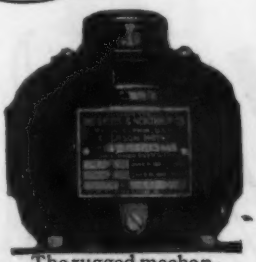

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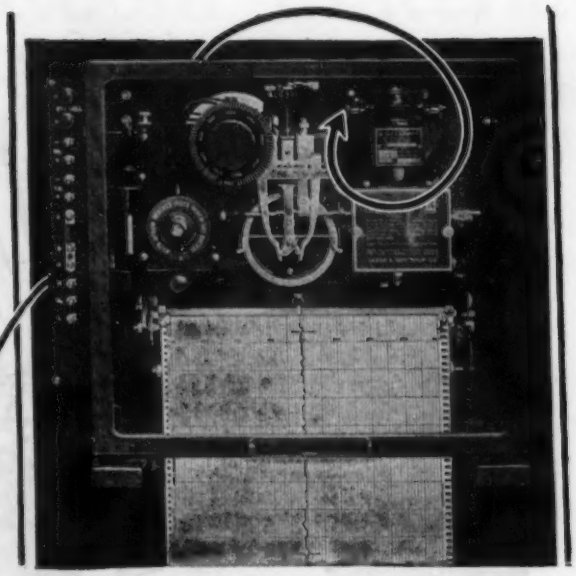

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SO THAT'S THAT.

There is a persistent rumor that I have personally written a book. I am not denying the fact. I have written a half dozen in my time; but I have never yet published one, unless it should so happen that this last one is published. One of the prominent publishing houses has done me the high honor to offer to publish it, and at the time this copy is being prepared I think it will be a go.

WHAT'S THE NAME?

YOU WILL HEAR THAT SOON ENOUGH.

If it is published I assure you that it will be a good book, and I ought to know, for I wrote it myself. That's one thing about me, I write my own stuff. Now don't write in and state: "It looks it," for there have been several others say that long ago.

But, of course, I have nothing to do with the writing of our technical publications. All such publications are compiled by The Houghton Research Staff.

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Chromium Metal
Chromium-Copper
Miscellaneous Chromium Alloys

ZIRCONIUM

Silicon-Zirconium
Zirconium-Ferrosilicon

SILICON

Ferrosilicon 15%
Ferrosilicon 50%
Ferrosilicon 75%
Ferrosilicon 80 to 85%
Ferrosilicon 90 to 95%
Refined Silicon (minimum 97% Silicon)
Calcium-Silicon
Silicon-Copper
Silico-Manganese (Manganese-Silicon)
Miscellaneous Silicon Alloys

MANGANESE

Standard Ferromanganese 78 to 82%
Low Carbon Ferromanganese
Manganese Metal
Manganese-Silicon (Silico-Manganese)
Manganese-Copper
Miscellaneous Manganese Alloys

VANADIUM

All Grades

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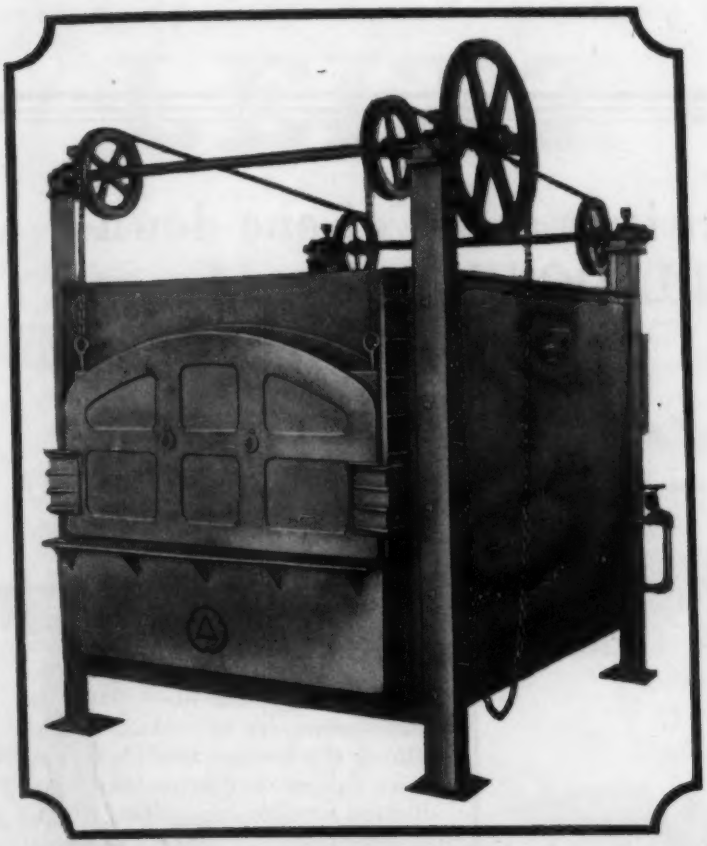

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Furnace

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Temperature Range 800° to 2000°F.

An eight-to-one turndown on the burners.

Full automatic control.

Reducing atmosphere constantly and automatically maintained.

Furnace operates without attention even where a change to higher temperature is required during the run.

Applicable to hardening, drawing, annealing, normalizing and a wide range of heat treating operations.

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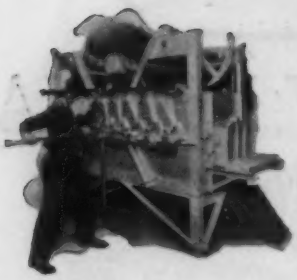
Utilization Division of the Combustion Utilities Corporation

It isn't a case of one down— ALL DOWN with



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¶A Globar Element can be replaced while the furnace is in operation—and inserted from the outside—

¶It is just a matter of a few moments—and all done while the rest of the Globar Elements are at required heat.

GLOBAR *Has Many Other Advantages*

ALL TOLD IN OUR TECHNICAL BULLETIN D-6

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LEITZ

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THE STANDARD OF OPTICAL AND MECHANICAL PRECISION

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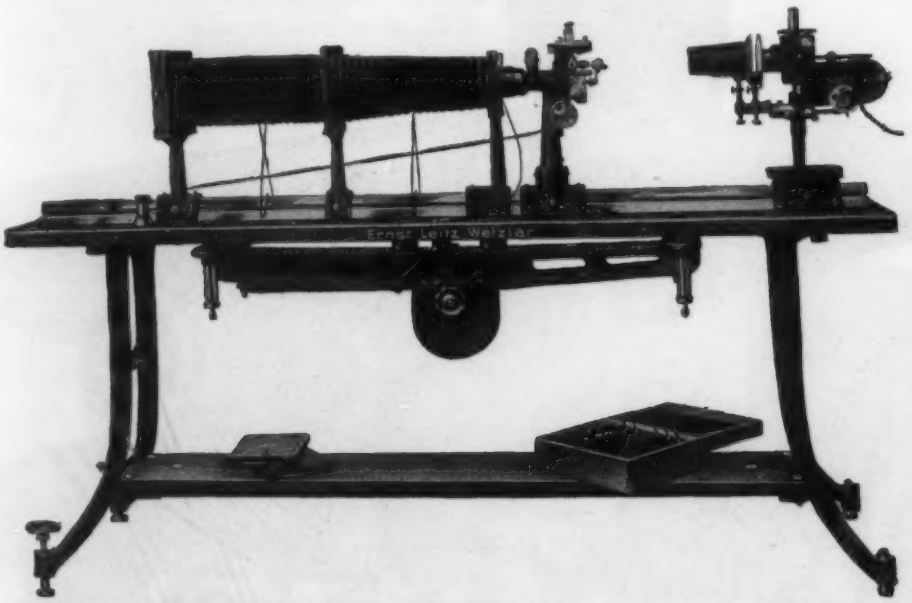

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Ample reduction.

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FOR THE SCIENCE AND ART

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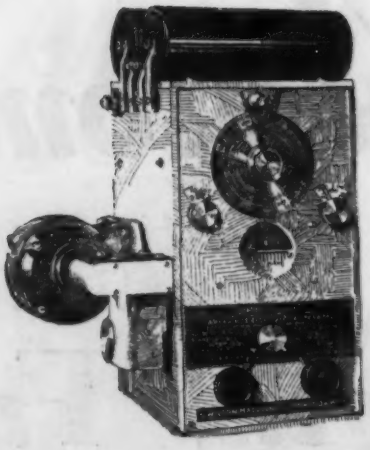

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Your instrument maker carries "Nichrome" Pyrometer Protection tubes in stock made only by the

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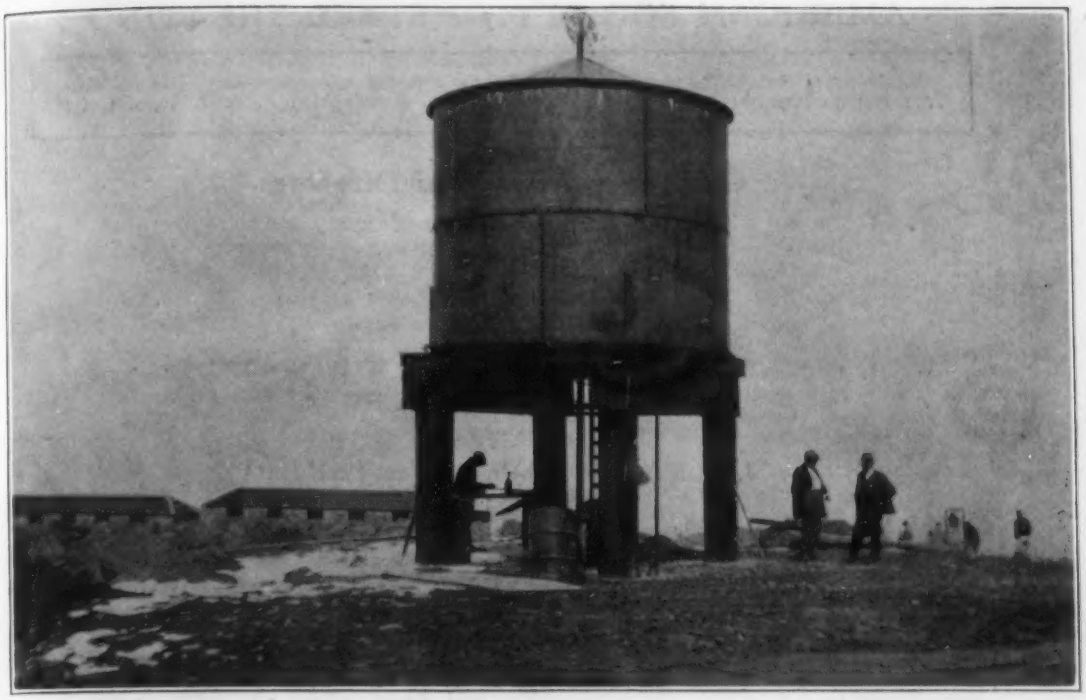

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The bath is 24" x 32" x 32" (deep) and holds 67 gallons of oil when two-thirds full. It holds at 375° F. on about 3 K. W. Similar baths are also installed in the Ford and Lincoln plants. For more facts, write for Catalog 51-M.

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BOX BULLETIN

Published by
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GENERAL ALLOYS COMPANY

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EVERY four years you can play the long shots with four or five to one against them if you have your own money to lose and enjoy risking it. That appeals to the "gambling instinct" which is a small part in the human brain that the phrenologists have not located. It's really "ego," that instinct.

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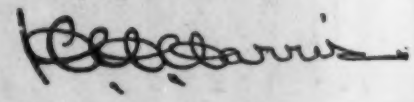

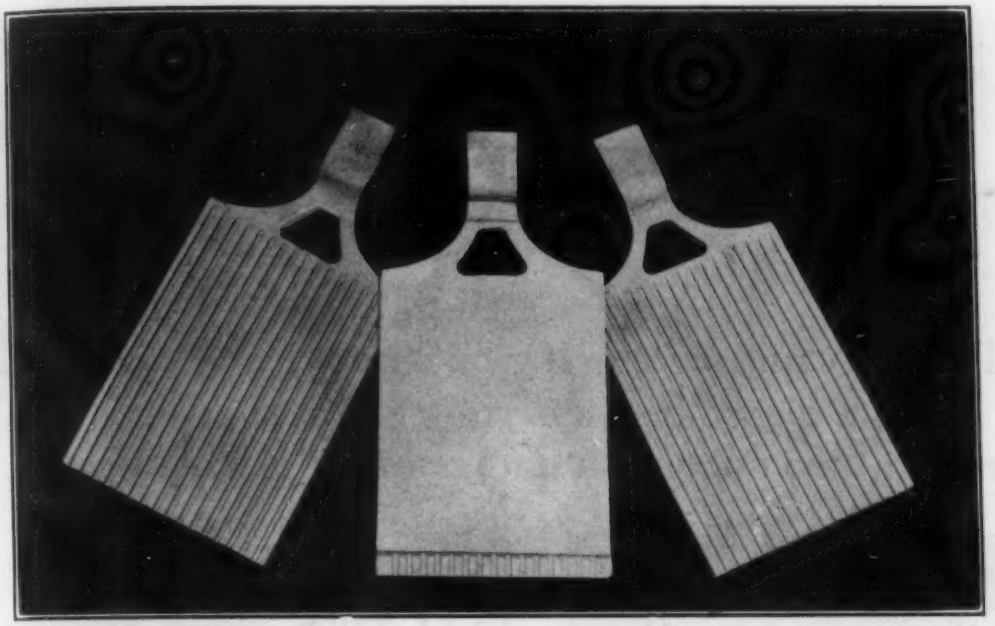

Not Butter Paddles--Neither Are They Battery Grids

—but they are as mechanically perfect as a die cast battery grid plate and clean enough to roll butter balls if necessary.

A far-sighted engineer who improves his process applying these bits of Q-Alloy wanted good alloy and got it by the expeditious process of ordering the highest grade alloy made, getting sound, clean castings up to his expectations. The castings are certainly Q-Alloy and the photograph unretouched, of course.

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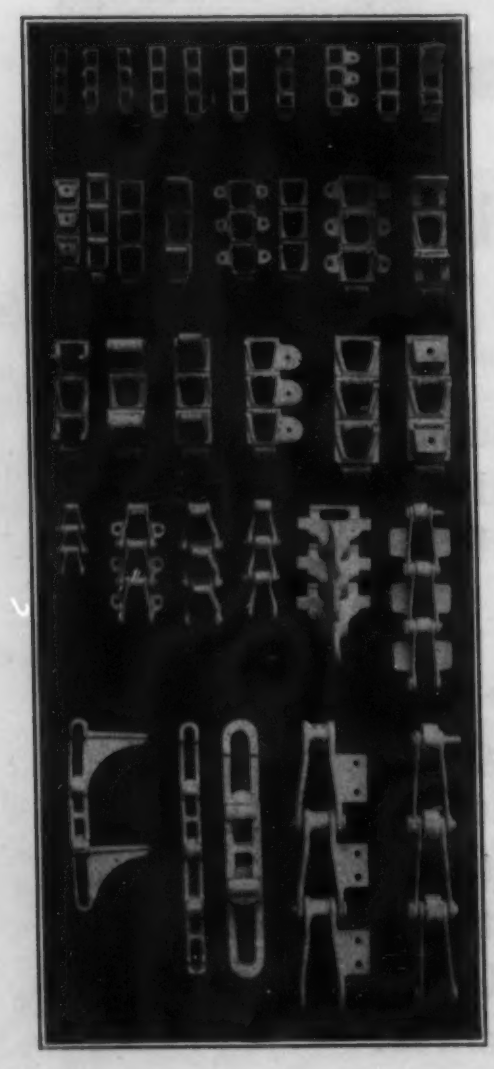
IT doesn't matter much what the requirement—there is quite apt to be a Q-Alloy chain to meet it if high temperature operation enters into the specification.



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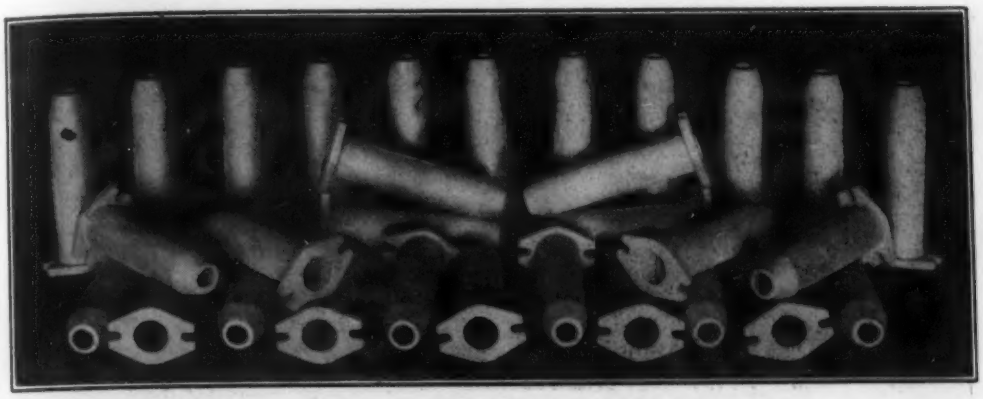
These are only a few of the standard links available. *Where can you use hot working chain to advantage?*



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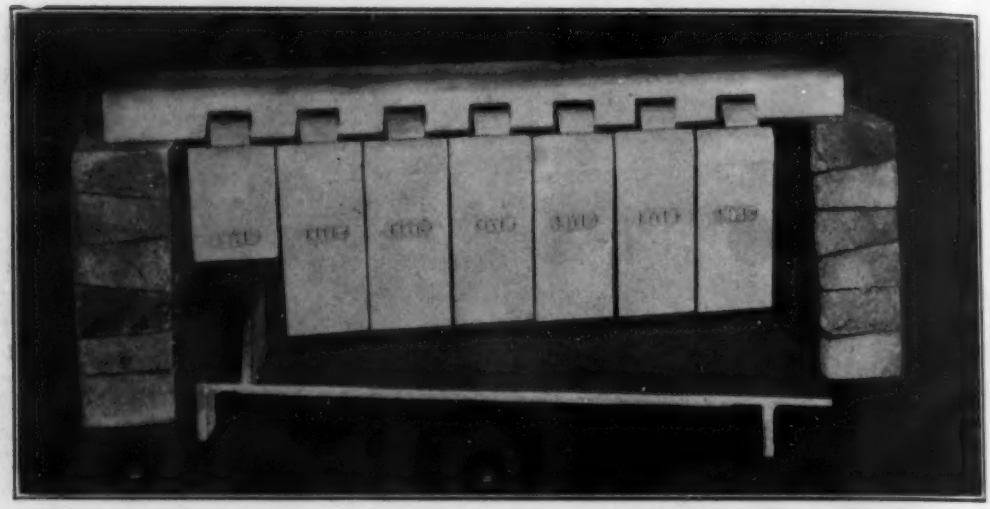
with good, dependable service are a great economy over the old fashioned kind that crack, burn and gum up with oxide.

Give your furnaces a chance to produce uniform work by feeding them uniform fuel. Burner tips are just another one of the small items where an ounce of good alloy in the right place may be worth a twenty dollar bill in plant economy.

What have you in your plant that would last longer and give better service and be cheaper in ultimate cost if it were made in Q-Alloy?



Holcroft Improved Rotary

HERE we have a free swinging X-ite baffle wall installed as part of a Holcroft Rotary Furnace. Note the section of X-ite hearth plate for the same furnace set in place below the swinging baffle. A 100% X-ite installation on an exacting job.

This type of rotary furnace is finding wide utility in many of the largest plants and has a great many uses. It can handle large or small parts for annealing, can be used for box carburizing, is practical in use where a fixed cycle semi-automatic furnace is required.

The large majority of furnaces of this type are equipped with Q-Alloy or X-ite parts. If you have purchased a furnace with inferior alloy parts specify Q-Alloys when ordering replacement parts from your furnace builder.

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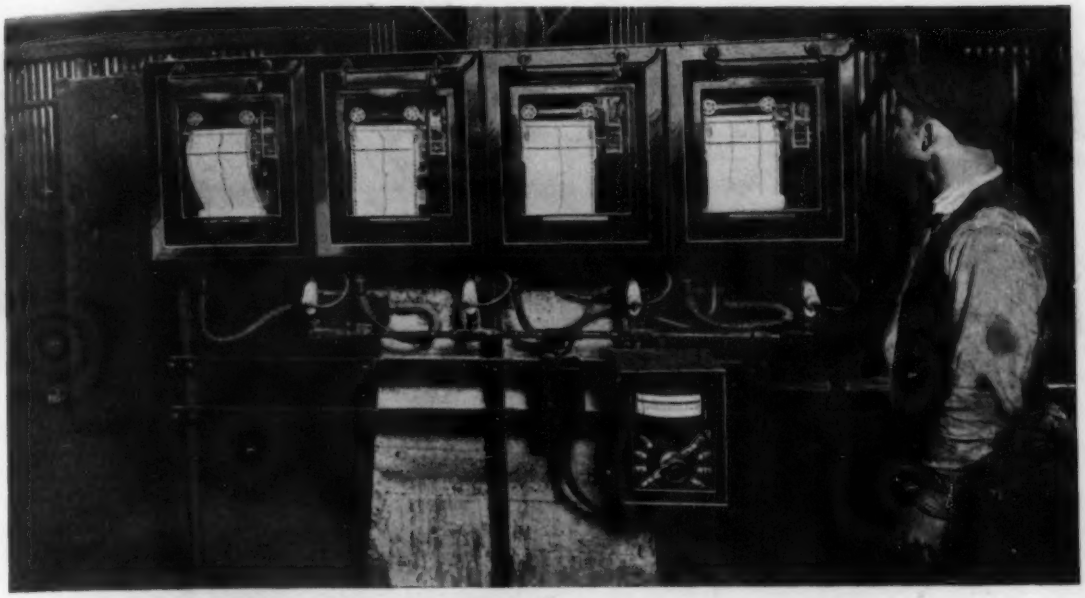

POT ANNEALING

FIVE Brown Pyrometers—four recorders and one indicator—are seen in this picture as installed for the regulation of temperature in eight gas-fired pot annealing furnaces of the Gulf States Steel Company. This is an excellent example of a Brown Recording Pyrometer installation with the instruments mounted in protecting cases which effectively shield the recorders from dust, moisture, fumes and mechanical injury. Let Brown engineers solve your heat treating problems. Write for Catalogs 15 and 87. Brown Instrument Company, 4452 Wayne Avenue, Philadelphia, Pa. Branches in 20 principal cities.

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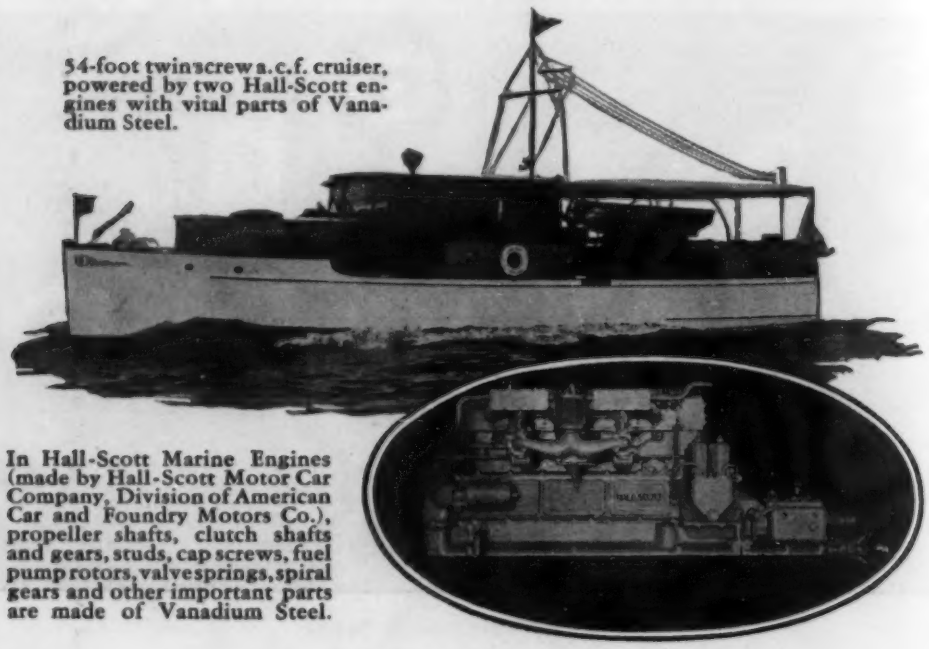
Brown Pyrometers

54-foot twin-screw a. c. f. cruiser, powered by two Hall-Scott engines with vital parts of Vanadium Steel.



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With Vital Parts of Vanadium Steel

REQUIRING almost constant maximum load and power output, marine service is most exacting on the engine. Gears, shafts and springs are subjected to severe stresses that test their stamina.

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"Checks purchased material. Saves tool breakage. Was formerly done outside. Olsen speeds up production and avoids guesswork. Had no trouble and has paid for itself on number of tests made and saving of tools."

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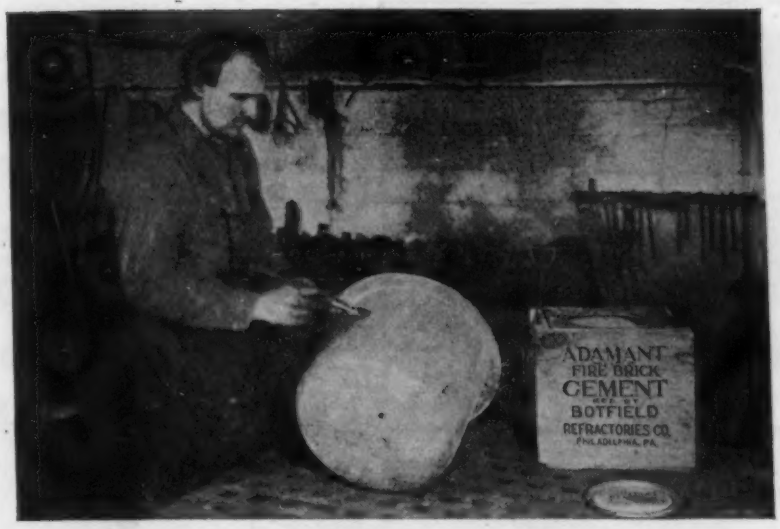

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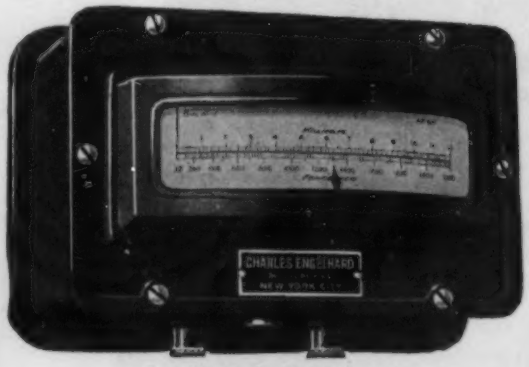

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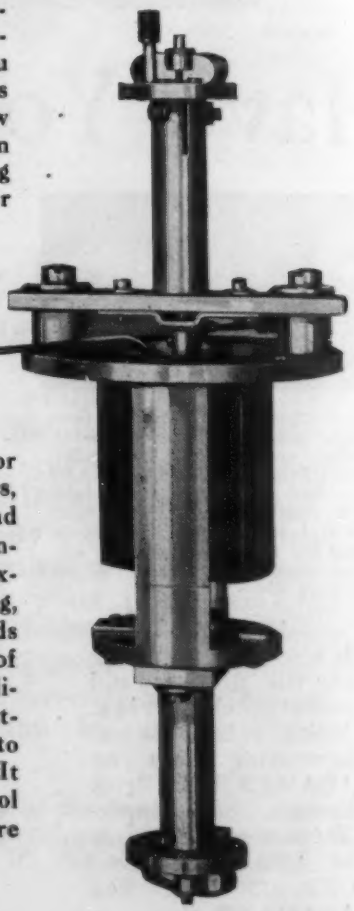

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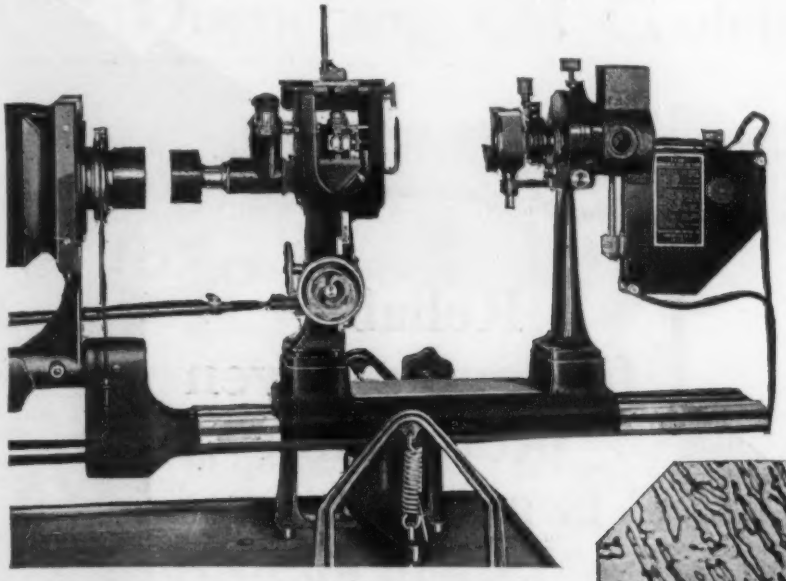

Cast iron specimen. Magnification 1500x. Note the perfect definition and flatness of field.

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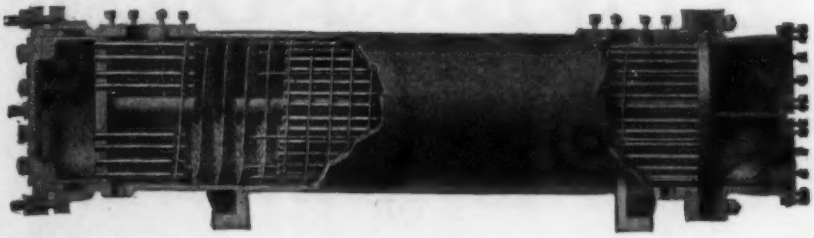

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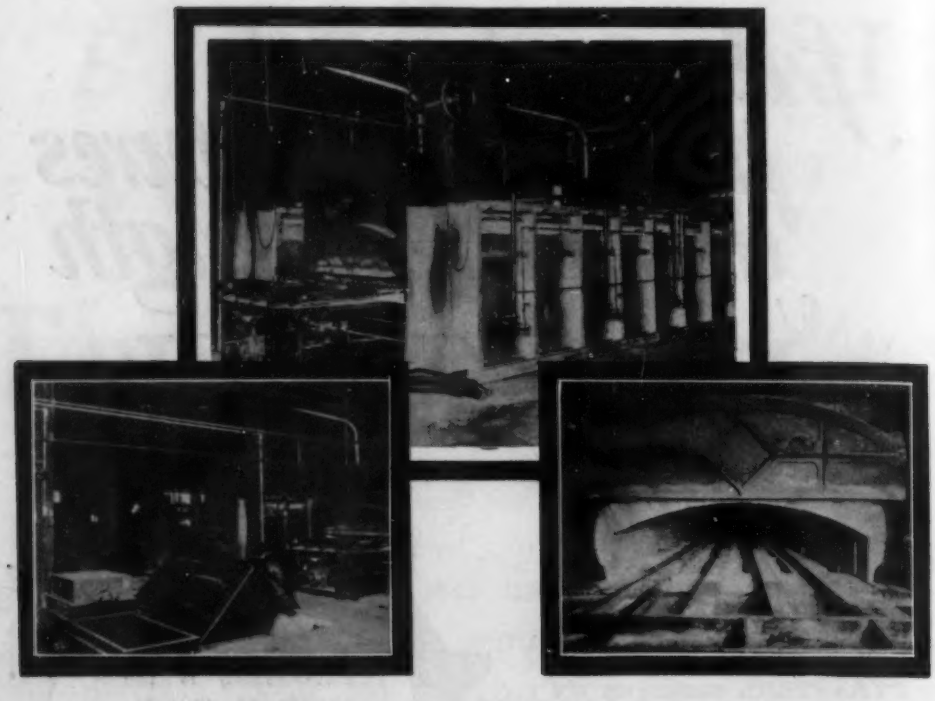

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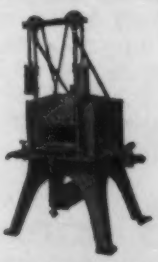

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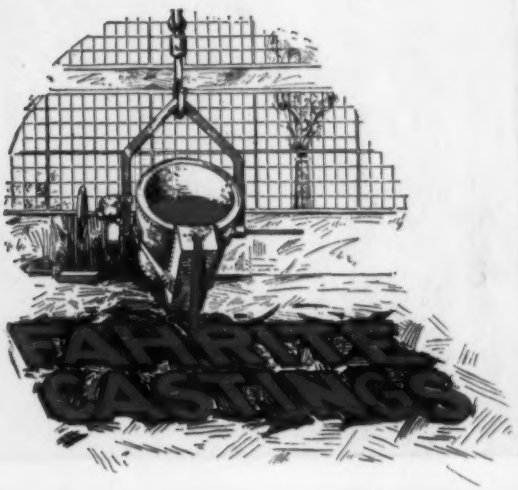

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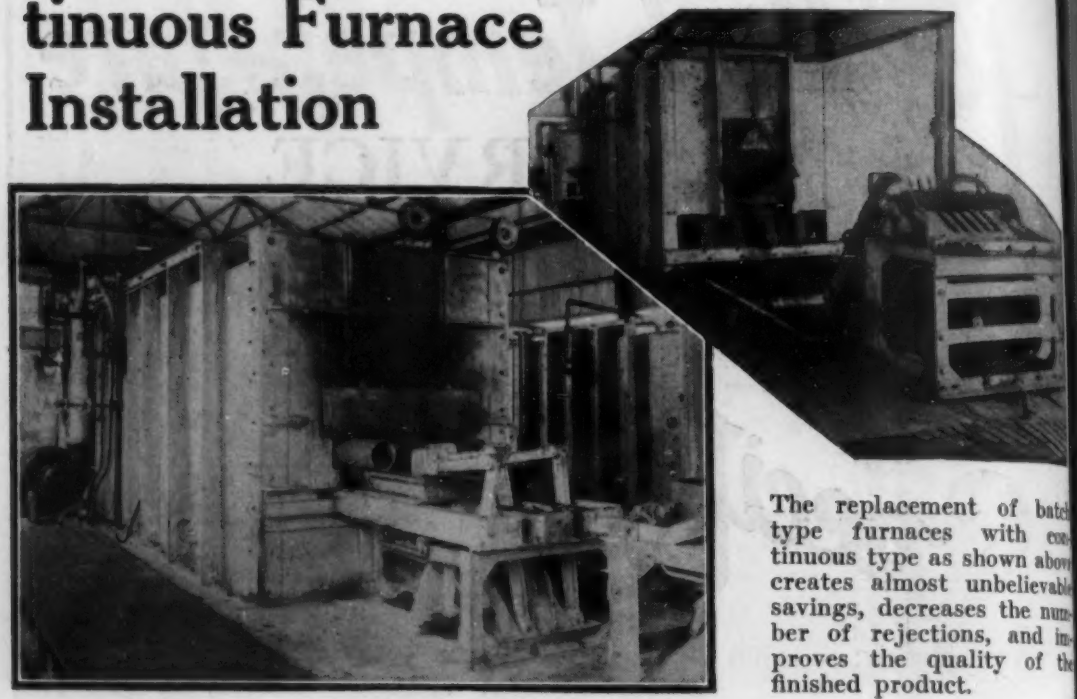

The replacement of batch type furnaces with continuous type as shown above creates almost unbelievable savings, decreases the number of rejections, and improves the quality of the finished product.

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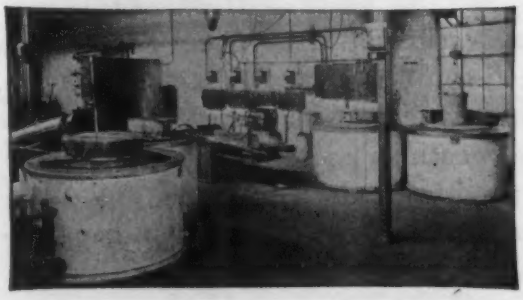

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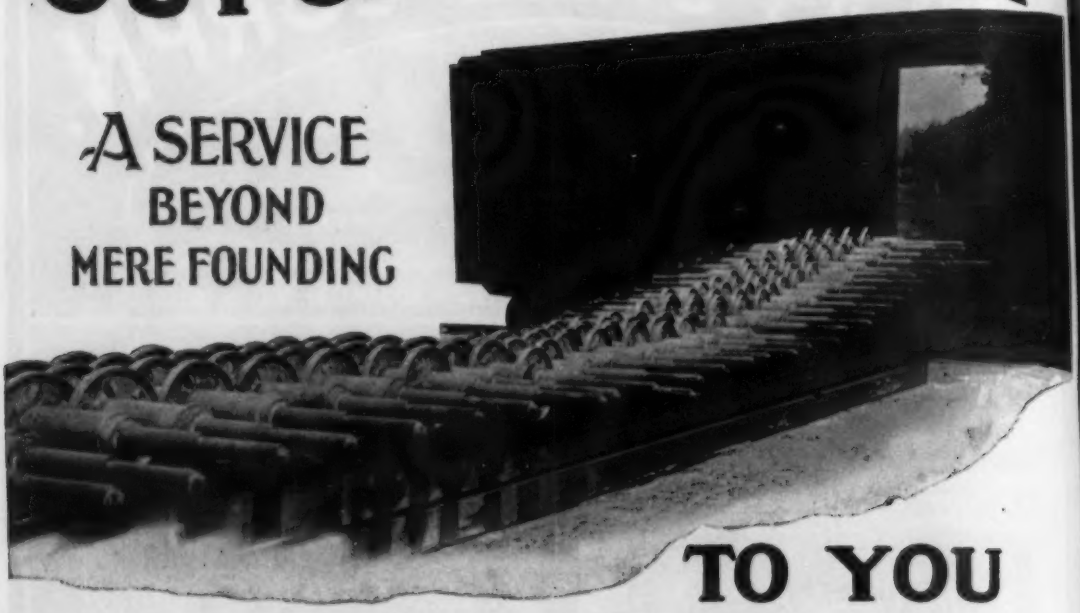

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IN hardening the races for thrust bearings the machine shown above replaced three pot furnaces. One man is required to operate instead of three, and the same high standard of quality is obtained.

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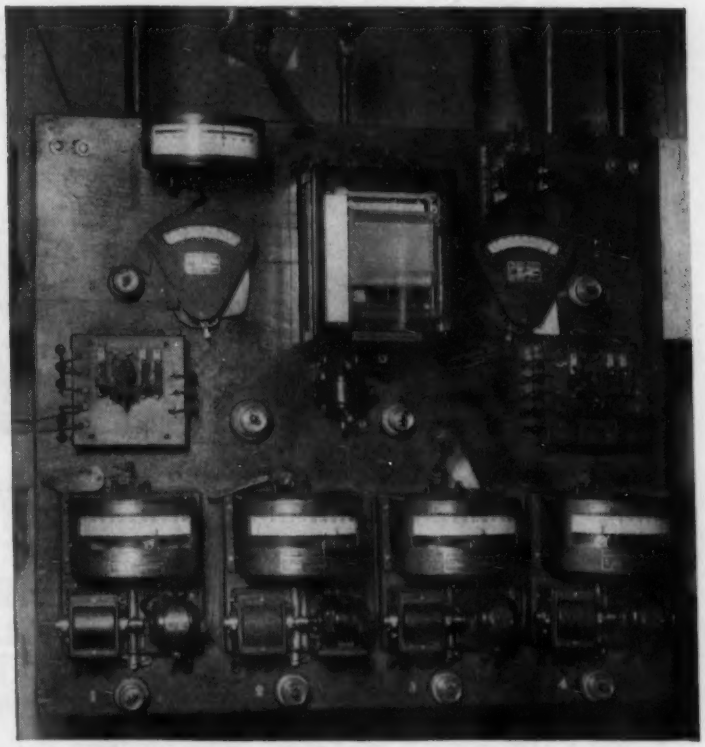

Control panel includes 4 Pyrometer Controllers; 2 Thermometer Thermostat Controllers; Indicating Pyrometer and Strip Chart Multiple Record Pyrometer.

DURING heat treatment of high quality dies, tools, machine screws, and various machine parts, the Bristol's equipment shown in accompanying illustration is used to automatically indicate, record and control the several phases of heat application.

Under such control, each batch of material is uniformly treated. Loss from "rejects," "seconds," and spoiled material is virtually eliminated, and standardized production on a high quality basis made possible.

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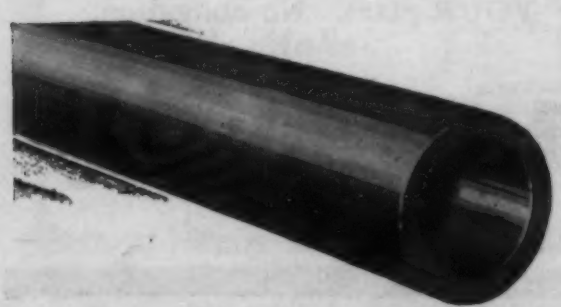

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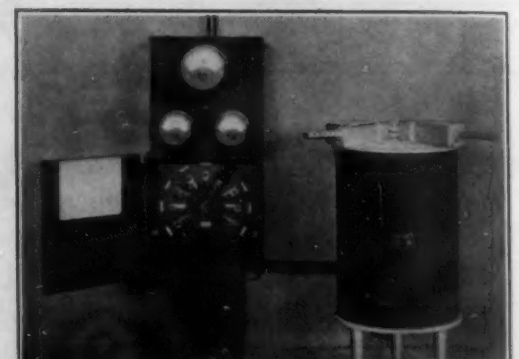

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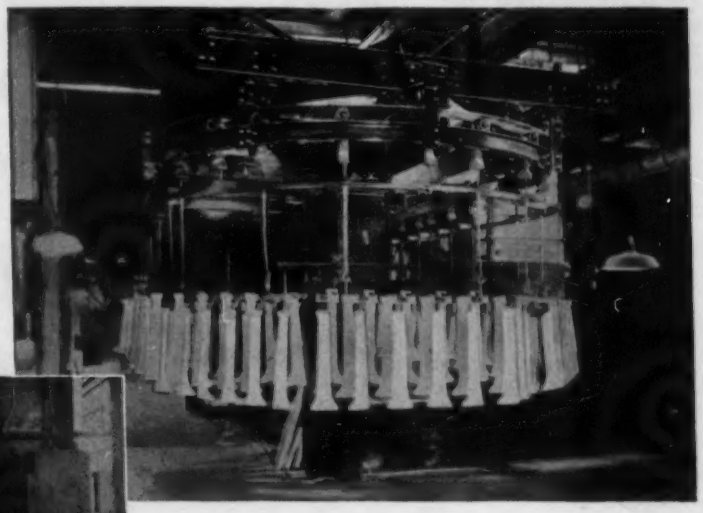

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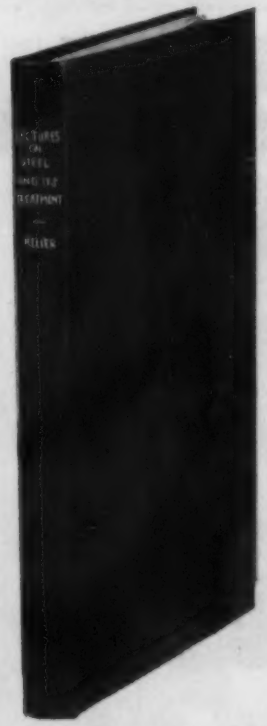

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and

Director of Engineering Extension Work, American Society for Steel Treating

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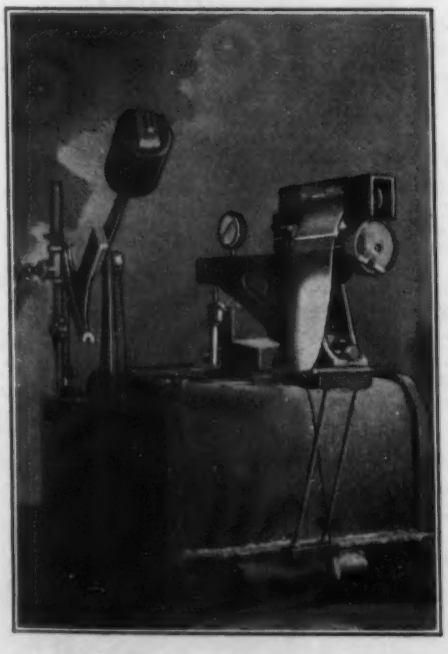

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(See Opposite Page for Classification)

I hereby make application for [Member / Sustaining] * *membership in the above Society and attach herewith* $..... *for dues to March first next, according to the table on reverse side of the sheet. I agree, if elected, that I will be governed by the Constitution, By-Laws and Rules of the Society as long as I continue to be a member. I furthermore agree to promote the objects of the Society so far as it shall be in my power.*

.....
Signature of Applicant

The annual dues† for membership, payable in advance, are:

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Dues Until March First Next Must Accompany Application

(See table on next page)

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In what department are you located?.....

Title or Position with said Firm.....

To which Chapter do you wish to belong?.....

Home Address .....
Unless requested, your mail will be sent here

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Sustaining Members please designate a representative here

Endorsed by .....
If candidate does not know any member of the Society, a reference will be satisfactory

All members in good standing will receive TRANSACTIONS and a bound volume of the HANDBOOK issued during the period of such membership

*Special application form for Junior Membership will be sent on request.

†$5.00 of the annual dues is for one year's subscription to the TRANSACTIONS of the American Society for Steel Treating.

(See opposite page)

CLASSIFICATION OF MEMBERSHIP

AMERICAN SOCIETY *for* STEEL TREATING

The following paragraphs from the Constitution should enable you to properly fill the application form on the opposite page:

Art. IV. Section 1. (c) "A MEMBER shall be a person twenty-one years of age or over, who is engaged in work related to the manufacture or treatment of metals, or the arts connected therewith."

* * * *

(d) "SUSTAINING MEMBERS shall be those persons, firms or corporations, who, because of exceptional interest in the work of the Society, contribute the annual dues of Sustaining Members as hereinafter set forth."

Membership in this class will be awarded to those who contribute a minimum of $25.00 yearly, and will be acknowledged by printing the firm or member's name (if the Sustaining Member be an individual) in each issue of the Society's TRANSACTIONS under the caption "Sustaining Members". A large number of firms holding Sustaining Memberships are paying annual dues of $100.00 per year.

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Each Sustaining Member, if a corporation or partnership, should designate on the application some individual to represent the firm. The Sustaining Membership carries with it the privileges of the Society for but one person, who votes in the name of the company, and who receives the publications and other data. This designation may be changed at the will of the company by notifying the National Office.

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Feb. 15 to Mar. 14	10.00	25.00	50.00	100.00
Mar. 15 to Apr. 14	9.17	22.92	45.83	91.67
Apr. 15 to May 14	8.33	20.83	41.67	83.33
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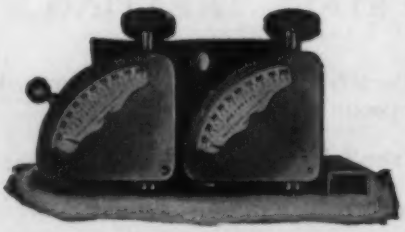

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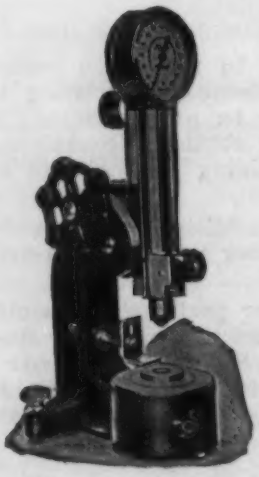

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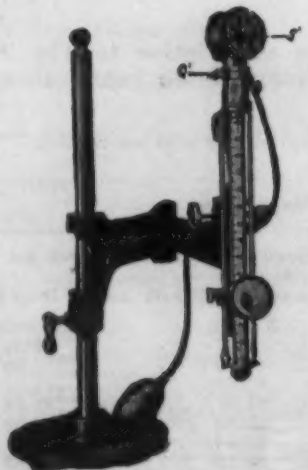

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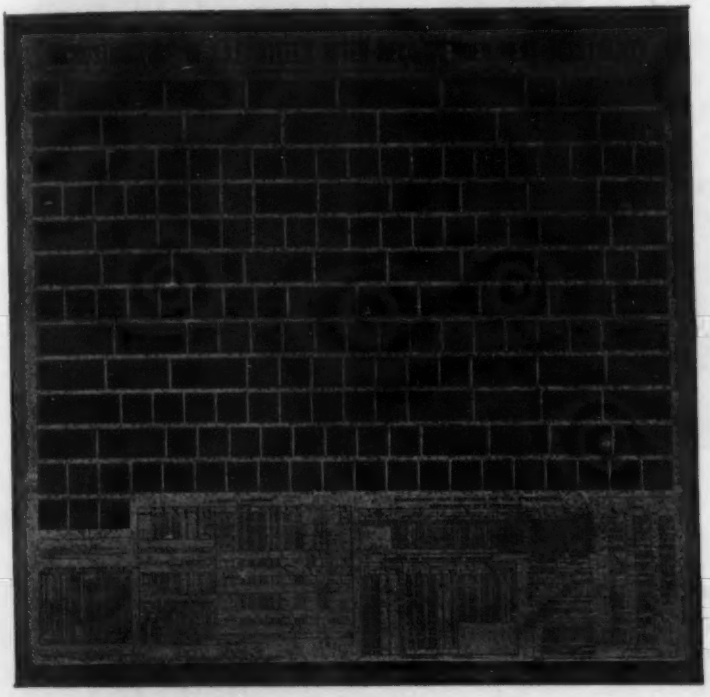

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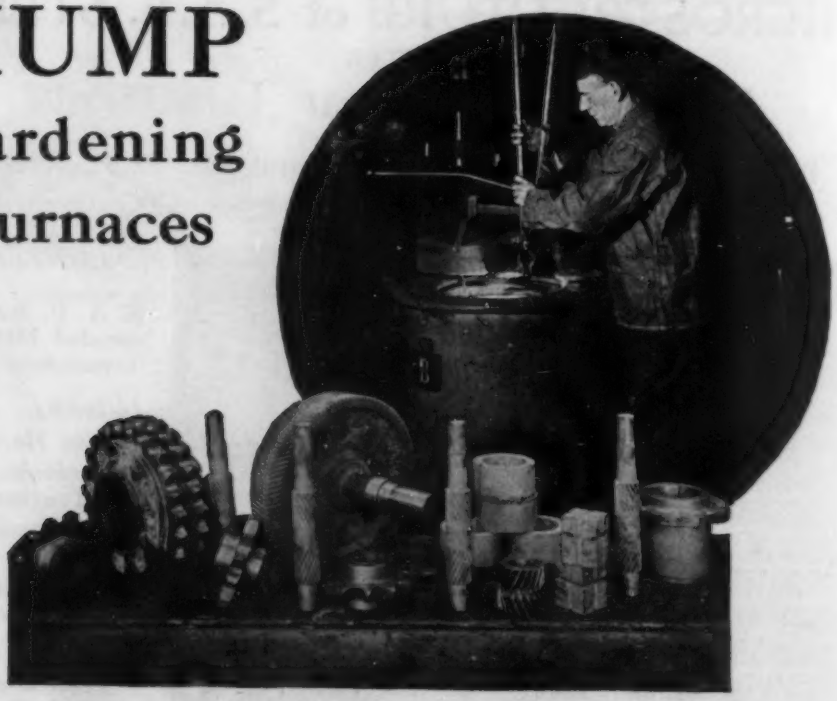

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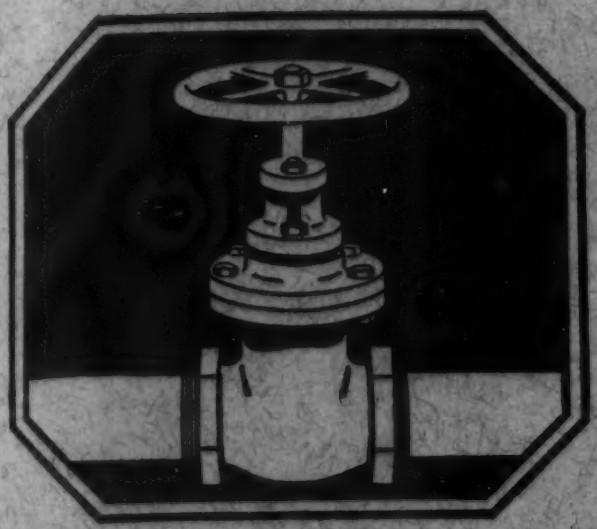

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YOU CAN DO IT BETTER WITH GAS

The New Lavite Electric Furnace

The heat is generated by the current passing thru the bath itself. This method of heating at once eliminates the necessity for the pot and its surroundings being hotter than the bath. The heat is generated right in the bath, where it is desired, and the temperature gradient is downhill all the way from the bath out through the pot and support. Also, the pot can be mounted in a heat insulating support with no limit to its thickness, which means great economy in power consumption, and protects the pot on the outside from the atmosphere so that, coupled with the lower pot temperature for a given bath temperature, the life of the pot is prolonged indefinitely.

This method achieves almost ultimate simplicity, for there is no apparatus at all around the pot—no burners, no chambers, no coils, no water cooling with its supply and waste piping, nothing but the bare pot set in a heat insulating support, with an electrode dipping into the bath.

Since the heat is not forced to flow through the pot wall into the bath, there is no limit to the amount of heat which can be supplied. Power can be put in at a rate to permit production as fast as the pieces can absorb heat from the bath, without any overheating of the furnace structure and there is no limit to the size or shape of pot.

Let us advise you, without obligation, how to apply it to your heat treating.

THE

Bellis Heat Treating Co.

BRANFORD, CONN.

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